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Managing Radical Innovation in an Open Environment

Matti Pihlajamaa

Managing Radical Innovation in an Open Environment

Matti Pihlajamaa

A doctoral dissertation completed for the degree of Doctor of Science (Technology) to be defended, with the permission of the Aalto University School of Science, at a public examination held at the lecture hall AS1 of the school on 14 June 2018 at 12.

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The capability to innovate is increasingly at the core of the success and survival of companies. The development of new products, services, and ways of doing business is needed to respond to changes in the companies' operating environments. Often it is not sufficient to improve existing products and services. Instead, companies aim to develop radical innovations which encompass novel technologies or require new markets, and have the potential to create paradigm shifts at the market, industry, or world level. The development of radical innovations is, however, difficult due to high uncertainties, and managers must implement changes to processes, organizational structures, firm culture, and external linkages to overcome these difficulties. Recently, researchers have paid particular attention on studying how open innovation, i.e. interactions with external sources of ideas and innovations, may help companies introduce radical innovations.

In this dissertation, the challenge of developing radical innovations in an open environment is investigated through four studies, each of which will provide complementary viewpoints to this problem. The first study investigates how knowledge from customers and users may help B2B manufacturing companies develop digital innovations. The findings indicate that in a situation where new digital technologies have created vast opportunities for innovation, customers have limited abilities to predict their future needs and companies need to turn to their users and aim to understand their latent needs to be able to set goals for radical innovation.

The second study investigates whether and how a company with a low level of internal R&D may introduce radical innovations based on its suppliers' technologies. The findings suggest that high investments in internal R&D are not necessary if the company has sufficient supplier management capabilities for establishing and managing successful collaboration.

The third study addresses the integration of radical ideas from outside an R&D unit's usual idea sources. In this setting characterized of high uncertainty mechanisms, which typically promote turning ideas into new products, are not available, and the integration of ideas relies on coordination mechanisms that facilitate knowledge exchange across disciplinary and hierarchical borders.

Finally, the fourth study addresses individual motivation in radical innovation development. It is found that multiple managerial actions at individual, team, and organization level related to goal assignment and organizational support influence the developers' motivation toward radical innovation development tasks. Therefore, it is important to evaluate the motivational effects of innovation methods. This general requirement is highly relevant also for open innovation.

The dissertation brings attention to the variety in approaches that companies may adopt in using open innovation to promote radical innovation and reports of methods and challenges in doing so.

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Tiivistelmä

Kyky innovoida on kasvavissa määrin tärkeää yritysten menestykselle ja selviytymiselle. Nykyisten tuotteiden ja palvelujen parantaminen ei usein ole riittävää, ja yritykset pyrkivät kehittämään radikaaleja innovaatioita, jotka perustuvat uusiin teknologioihin tai vaativat uusia markkinoita ja jotka voivat synnyttää merkittäviä muutoksia markkina-alueen, toimialan tai maailman näkökulmasta. Radikaalien innovaatioiden kehittämiseen liittyy haasteita johtuen korkeasta epävarmuuden asteesta ja johtajien täytyy tehdä muutoksia yritystensä prosesseihin, organisaatorakenteisiin, kulttuuriin ja ulkoisiin suhteisiin. Avoimen innovaation, eli yhteistyön ulkoisten ideoiden ja innovaatioiden lähteiden kanssa, on havaittu voivan auttaa yrityksiä tuomaan markkinoille radikaaleja innovaatioita.

Tässä väitöskirjassa radikaalien innovaatioiden kehittämistä avoimessa ympäristössä tarkastellaan neljän tutkimuksen kautta. Ensimmäinen tutkimus tarkastelee miten asiakkailta ja käyttäjiltä saatava tieto voi auttaa valmistavan teollisuuden B2B-yrityksiä kehittämään radikaaleja digitaalisia innovaatioita. Löydösten mukaan tilanteessa, jossa uudet digitaaliset teknologiat ovat luoneet mahdollisuuksia innovoinnille, asiakkailla on rajattu kyky ennustaa tulevia tarpeitaan ja yritysten tulee pyrkiä ymmärtämään tuotteidensa käyttäjien piileviä tarpeita voidakseen asettaa tavoitteita radikaalille innovaatiotoiminnalle.

Toinen tutkimus selvittää, miten matalan T&K-intensiivisyyden yritys voi tuoda markkinoille uusia radikaaleja innovaatioita, jotka perustuvat sen toimittajayritysten kehittämiin teknologioihin. Tutkimuksen tulokset näyttävät, että korkeat T&K-investoinnit eivät ole välttämättömiä, mikäli yrityksellä on toimittajien johtamiseen liittyviä kyvykkyyksiä, joita se voi hyödyntää yhteistyösuhteen käynnistämisessä ja ylläpidossa.

Kolmas tutkimus käsittelee radikaalien ideoiden omaksumista idealähteistä, jotka eivät ole tavanomaisesti yrityksen T&K-yksikön käytössä. Tutkimuksen mukaan korkea epävarmuus voi estää ideoiden jatkokehittämisessä tyypillisesti hyödynnettyjen mekanismien käytön ja ideoiden omaksuminen ja hyödyntäminen ovat riippuvaisia koordinaatiomekanismeista, jotka edistävät tiedonvaihtoa yli hierarkkisten ja oppialallisten rajojen.

Neljäs tutkimus käsittelee yksilötason motivaatiota radikaalien innovaatioiden kehittämisessä. Tulosten mukaan useat tavoitteisiin ja tukeen liittyvät johtamistoimenpiteet yksilö-, tiimi-, ja organisaatiotasolla vaikuttavat kehittäjien motivaatioon radikaalien innovaatioiden kehittämistä kohtaan. Innovaatiojohtamisen menetelmiä tulee siis tarkastella niiden motivaatiovaikutusten näkökulmasta. Tämä yleinen periaate on keskeinen myös avoimessa innovaatiotoiminnassa.

Tämä väitöskirja korostaa moninaisuutta lähestymistavoissa, joita yritykset voivat omaksua hyödyntäessään avointa innovaatiota radikaalien innovaatioiden kehittämiseksi, ja käsittelee niihin liittyviä menetelmiä sekä haasteita.

Avainsanat innovaatiojohtaminen, radikaali innovaatio, avoin innovaatio, tapaustutkimus

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This dissertation is the result of a lengthy process, which has been both extremely frustrating and – at the same time – remarkably fun and rewarding. It has been characterised by great uncertainty: most of the time it has been unclear whether the finishing line is near or far and if the steps taken have been in the right direction. Besides the four journal articles and the summary part that comprise this dissertation, I have written hundreds of pages of text that are not included and spent countless hours on side projects and dead ends. Nevertheless, I would not have it any other way. While the tangible outcome of the process is this book, the most important results are intangible. Every setback, new theory, data set, and methodological problem has led to valuable insights on how to make sense of the world around me. In addition to academic and professional value, these insights have also influenced me at a deeply personal level. Throughout the process, I have learned to think and discuss in new ways and see the world through different eyes. For me, there lies the real value of this dissertation. While there are many ways to complete a doctoral degree, at this point I feel glad not to have experienced the most straightforward one. By taking some detours, I have been able to immerse myself in several interesting topics, which has brought me immense joy and enthusiasm.

Writing a dissertation often feels like a very individual endeavor. It, however, does not happen in a vacuum. I have been extremely lucky to have worked in a supportive environment surrounded by terrific people who have made the journey much easier and way more fun than it would have otherwise been.

When I first joined Aalto University to work on my Master's thesis on innovation policy, I had little understanding about the intricacies of management, organization studies, or qualitative research. I, however, became part of a very special research group, Innovation Management Institute (IMI), where the phenomenon of innovation was approached with a variety of perspectives by people of diverse backgrounds. I was impressed by how insights from multiple disciplines such as sociology, economics, and psychology were combined to understand practical problems. This multidisciplinary setting was extremely inspiring for me. Even more so, the warm and close community at IMI was crucial in invoking thoughts that perhaps a doctorate could be something to aspire for. I am very grateful for fellow IMI colleagues, especially Pekka Berg, Tuomo Eloranta, Laura Kanto, Jukka-Pekka Kevätsalo, Tea Lempiälä, Jaana Näsänen, Jussi Pihlajamaa, Kirsi Polvinen, and Outi Vanharanta. I am forever thankful for the friendships, long discussions, and late

nights (and early mornings) at the office. Without you, I would probably be doing something completely different.

When I decided on applying for a doctoral candidate position, I met Professor Eero Eloranta who agreed to become my supervisor. I am thankful for his continuous support and encouragement during the years. It has been a privilege to have a professor who has trusted me to find my own way and believed that my academic explorations will eventually bear fruit. Based on his vast supervision experience, Eero has also provided great no-nonsense insights about how the academic world works, which has made its peculiarities easier to digest.

A couple of years ago, I joined the Logistics Research Group (LRG) to participate in a research project on supplier innovation management. This transition was extremely valuable as I got to further broaden my perspectives and work with some extremely talented people. I owe thanks to Professor Kari Tanskanen and Riikka Kaipia who decided to choose me – someone from a floor above in the middle of his dissertation work – for the job instead of some prestigious international applicant. Working in LRG has drawn my interest to the fascinating field of purchasing and supply management and it has been an absolute pleasure to investigate innovation management in this domain together. I wish to thank Riikka for the endless support and being a wonderful friend and colleague to work with, and Kari for all the insightful comments and providing me a safe and stable environment for finalising the dissertation. In addition, I am grateful for Anna Aminoff, for all the stimulating discussions, more of which will undoubtedly come. Some of the most enlightening moments of the last years have taken place with Riikka, Kari, and Anna in Kari's room where we have been discussing the details of management theory and research design. Working with them has taught me a lot on how high quality research is conducted. I also wish to thank Raphael Giesecke and Mervi Vuori for being there to share the ups and downs of finalizing a dissertation. Beyond those who have mentioned here, there have been numerous people at Aalto who have given ideas and assistance and have been a part of the environment that have made it possible for me to do my research.

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Further thanks go to the co-authors of the publications that are included in this dissertation: Thomas Abrell, Laura Kanto, Jan vom Brocke, Falk Übernickel, Riikka Kaipia, Julius Säilä, and Kari Tanskanen. In addition, there are colleagues who have participated in the research processes in one way or

another without being listed as authors. I am grateful for their efforts and hope that I have also been able to help them in one way or another. Further thanks go to the companies that have allowed me to investigate their operations. Without there being managers willing to open up their doors for researchers, allocate time for discussions and interviews, and share their ideas and knowledge, none of this would have been possible.

This dissertation would not have been completed without financial support. I have been lucky to have worked in relevant research projects and received personal grants that have enabled me to advance the dissertation – something that is not to be taken for granted in the current research environment. I want to thank those who have supported this research: Tekes – The Finnish Funding Agency for Innovation, companies participating in the research projects, Yrjö Uitto Foundation, KAUTE Foundation, Otto A. Malm Foundation, the Foundation for Economic Education, and the Department of Industrial Engineering and Management at Aalto University School of Science.

Academic work and extremely long projects such as doctoral dissertations can easily occupy one's mind leaving little room for anything else. I have been lucky to be surrounded by family and friends who have never made it possible for me to forget that the truly important things in life are not found in books and academic journals. I want to thank everyone for listening to my rants and especially for putting things into perspective by not being too interested in the details. Special thanks go to my father, Jussi, who has been a great mentor, colleague, and someone to share my steps toward the dissertation with. I believe the academic world needs more people with his empathy and ability to not get lost in the jargon but remember that in the end our goal should be to help people solve their problems and make the world a little bit better place.

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Helsinki, 6 May 2018
Matti Pihlajamaa

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List of publications

This doctoral dissertation consists of a summary and of the following publications, which are referred to in the text by their numerals

- 1.** Abrell, Thomas; Pihlajamaa, Matti; Kanto, Laura; vom Brocke, Jan; Uebernickel, Falk. 2016. The role of users and customers in digital innovation: Insights from B2B manufacturing firms. *Information & Management*, volume 53, issue 3, pages 324–335. doi:10.1016/j.im.2015.12.005
- 2.** Pihlajamaa, Matti; Kaipia, Riikka; Säilä, Julius; Tanskanen, Kari. 2017. Can supplier innovations substitute for internal R&D? A multiple case study from an absorptive capacity perspective. *Journal of Purchasing and Supply Management*, volume 23, issue 4, pages 242–255. doi:10.1016/j.pursup.2017.08.002
- 3.** Pihlajamaa, Matti. 2017. Absorbing radical ideas from unusual sources – the role of social integration mechanisms. *Technology Analysis & Strategic Management*, volume 30, issue 2, pages 131–143 + supplementary material (2 pages). doi:10.1080/09537325.2017.1297398
- 4.** Pihlajamaa, Matti. 2017. Going the extra mile: Managing individual motivation in radical innovation development. *Journal of Engineering and Technology Management*, volume 43, pages 48–66. doi:10.1016/j.jengtecman.2017.01.003

Author's contribution

Publication 1: The role of users and customers in digital innovation:
Insights from B2B manufacturing firms

The author of this dissertation is a co-first author of the publication, and participated in all stages of the research progress: research design, building the theoretical framework, data collection and analysis, and writing and editing the manuscript.

Publication 2: Can supplier innovations substitute for internal R&D? A multiple case study from an absorptive capacity perspective

The author of this dissertation is a first author of the publication, and participated in research design, building the theoretical framework, data analysis, and writing and editing the manuscript, and had a minor contribution to data collection.

Publication 3: Absorbing radical ideas from unusual sources – the role of social integration mechanisms

The author of this dissertation is the sole author of the publication.

Publication 4: Going the extra mile: Managing individual motivation in radical innovation development

The author of this dissertation is the sole author of the publication.

1. Introduction

The ability to innovate is a prevalent requirement for survival and success in many industries and the basis of economic progress (Romer, 1990; Schumpeter, 2004; Teece, 1996). Technological development and megatrends such as globalization, digitization, urbanization, and drastic increases in the amount of available information are examples of forces that induce constant changes to the environment which companies operate in. These changes bring about new opportunities to improve the quality of life for people and create new business, but at the same time they undermine the factors which made companies successful in the past. Innovation hence becomes a necessity for finding new growth and maintaining competitiveness in modern business environments.

Today, most large companies have adopted systematic innovation management methods which aim to develop new innovations in an efficient manner (Barczak et al., 2009; Griffin, 1997). They, however, often concentrate on incremental innovation, that is the improvement of existing products, services, and ways of doing business. In many cases, this is insufficient as there are others who are able to out-innovate them by generating innovations with bigger leaps in performance and customer value (Hill & Rothaermel, 2003). The situation resembles the Red Queen's race that is described in Lewis Carroll's (1998, p. 52) famous novel "Through the Looking-Glass", where the Red Queen character says that "It takes all the running you can do to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that." Consequently, companies aim to introduce highly novel radical innovations in addition to incremental ones.

Radical innovation is defined as products, services, or processes which encompass novel technologies or require new market structures, and which have the potential to create paradigm shifts at the market, industry, or world level (Garcia & Calantone, 2002) and it can be contrasted with incremental innovation, which addresses the improvement of existing products, services, or other aspects of business. Radical innovation has been of the interest of both academics and practitioners for a long time, which has generated a vast amount of studies on how it should be managed. Despite these efforts, it is by no means a fully understood phenomenon. There seems to be a mismatch between companies' innovation goals, which often put a strong emphasis on radical new-to-the-world products (Andrew et al., 2010), and the actual performance of their innovation activities (Barczak et al., 2009; Slater et al., 2014).

To explain these discrepancies, researchers have started to explore barriers which explain the lack of success in radical innovation endeavours (Assink, 2006; Sandberg & Aarikka-Stenroos, 2014). Many of these barriers appear to be related to increases in uncertainty that are often brought about by radical innovation. Innovation management systems in use in large companies are typically focused on contexts of low-to-moderate uncertainty (Cooper, 2014; Tidd, 1997; Veryzer, 1998). When there is high uncertainty over the potential and feasibility of new ideas the established methods are likely to perform poorly (Assink, 2006). In situations of high uncertainty, there is insufficient knowledge to make educated decisions and therefore the outcomes of actions may be unknown (Melander & Tell, 2014; Mullins & Sutherland, 1998). Such uncertainties may address, for example, questions of which are the most feasible technologies (Green et al., 1995), what do the customers wish to buy (Lynn & Akgün, 1998), and where to get resources for developing the innovations (O'Connor & Rice, 2013a). In response, companies have started to adopt processes and methods for experimenting with new technologies (Chang et al., 2012; Koberg et al., 2003; McGrath, 2001), establish separate organizational structures for radical innovation to decrease conflicts between their explorative and exploitative goals (Leifer et al., 2000), and promote culture which tolerates risk taking and failure (Herrmann et al., 2007; McLaughlin et al., 2008).

In addition, managers increasingly turn their attention to outside the boundaries of their own organization to gain access to resources and capabilities that are needed to develop radical innovations (Chesbrough, 2003, 2006) and move to what Chesbrough & Crowther (2006) call an open environment. A single company is not likely to possess all assets that are required to develop radical innovations (Geffen & Rothenberg, 2000), and collaborating with external partners and acquiring ideas, knowledge, and technologies from them may bring about new opportunities for breakthroughs (Kelley et al., 2013; Knudsen et al., 2017; Pilav-Velić & Marjanovic, 2016). This phenomenon of accepting a more open environment for innovation and collaborating with external partners for the purpose of innovation is commonly called *open innovation* (Chesbrough, 2003; Chesbrough & Crowther, 2006; Enkel et al., 2009).

It is argued that companies need to become open in order to develop radical innovations in a systematic way: *“Open innovation is quickly becoming viewed as a critical aspect to helping gain the efficiencies of learning necessary to make radical innovation sustainable. Any company choosing to develop radical innovations is, by definition, stretching the boundary of what is already known, certainly within its own domain. Accessing technologies, market partners, and expertise in arenas that are dramatically different from the company’s core enables creativity, opportunity recognition, and connectivity into new domains”* (O'Connor, 2006, pp. 79–80).

Open innovation is opposed to closed innovation. In closed innovation, companies try to do everything themselves. They can, for example, establish large R&D centres in order to conduct scientific research in interesting areas, explore applications for promising technologies, and create new products, and

services that other departments within the same corporation may then continue to manufacture, market, and sell. The adoption of open innovation practices has reportedly been useful in bridging the gap between the radical innovation goals that companies have and their actual performance (Kennedy et al., 2016; Pilav-Velić & Marjanovic, 2016), but there is also variation in how companies are able to benefit from open innovation (Gassmann et al., 2010). In addition to the difficulties arising from high uncertainties related to radical innovation, open innovation brings about its own challenges. Companies have to develop capabilities to evaluate external technologies and opportunities (Chiaroni et al., 2010; Hu et al., 2015), transfer and integrate external knowledge (Alavi & Leidner, 2001; Cohen & Levinthal, 1990), and manage relationships with their innovation partners (Fliess & Becker, 2006; Lakemond et al., 2016). Radical innovation and open innovation are both considered to be demanding (Chesbrough, 2004; Chiu et al., 2016; O'Connor & Rice, 2013a) and when open innovation is leveraged for the purposes of radical innovation the situation is likely to be even more challenging (Chesbrough, 2006; O'Connor, 2006) as companies need to ensure that their innovation management systems are not restricted to incremental and closed innovation.

The aim of this dissertation is to investigate challenges and methods related to the development of radical innovations in an open environment. The focus is, therefore, on situations where open innovation is leveraged for radical innovation. To make focused contributions to theory and practice, the dissertation includes four distinct studies which are associated with four specific research questions.

The first study investigates the role of users and customers in developing radical innovations. Users and customers are among the most important sources of knowledge about market needs and therefore valuable external partners for innovation (Chatterji & Fabrizio, 2014; Lettl et al., 2006). In the case, of radical innovation there is, however, an ongoing debate on whether the contributions of customers and users are limited to promoting incremental innovation (Agostini et al., 2016; Nicholas et al., 2015). Furthermore, customers and users have been rarely distinguished from each other in the literature. To investigate their separate contributions to companies' innovation processes, the study focuses on B2B manufacturing industry where a distinction between customers and users is evident. By investigating a context where the diffusion of new digital technologies creates opportunities for radical innovation, it is possible to investigate their value for radical innovation specifically. The first research question is defined as follows:

RQ1: How do B2B manufacturing firms leverage customer knowledge and user knowledge for the purposes of radical digital innovation?

The second study investigates a poorly studied question of whether companies may substitute their internal innovation activities with externally generated knowledge and technologies. Most extant studies argue that companies must have high internal innovation capabilities and resources in order to benefit from

external partnerships as new knowledge is difficult to integrate and exploit if the company does not have a sufficient amount of related knowledge in-house (Cohen & Levinthal, 1990; Dahlander & Gann, 2010; Hung & Chou, 2013). The study investigates a company with scarce in-house innovation resources which introduces radical innovations based on external technologies from its suppliers. The process of turning these external inputs into market-ready innovations is examined by looking at four capabilities acquisition, assimilation, transformation, and exploitation that are considered to explain an organization's ability to benefit from external knowledge (Todorova & Durisin, 2007; Zahra & George, 2002). Accordingly, the second research question is defined as:

RQ2: How do the capabilities of acquisition, assimilation, transformation, and exploitation manifest themselves in substituting internal R&D with supplier innovations?

The third study addresses an important way that open innovation may benefit radical innovation: the absorption of radical ideas from new sources that are not currently used. It is widely argued that new partners and idea sources need to be sought and contacted to gain access to highly novel ideas (Birkinshaw et al., 2007; Day & Schoemaker, 2004; Phillips et al., 2006), but that companies often fail to integrate these ideas (Cohen & Levinthal, 1990; Katz & Allen, 1982). It has been proposed that social integration mechanisms – a set of processes, systems, and norms that facilitate knowledge sharing and utilization within an organization – may affect a company's ability to integrate ideas (Jansen et al., 2005; Todorova & Durisin, 2007; Zahra & George, 2002). With this background, the third research question is defined as:

RQ3: How do social integration mechanisms influence the absorption of radical ideas from unusual sources?

Finally, the fourth study addresses motivational issues in radical innovation development. Previous studies have identified highly motivated individuals behind many successful radical innovation projects (Chakrabarti, 1974; Ettlie et al., 1984; Reid & de Brentani, 2004) and argued that a lack of motivated employees may be detrimental for a company's attempts to develop radical innovations (Alexander & van Knippenberg, 2014; Kelley et al., 2011; O'Connor & McDermott, 2004; Stringer, 2000). Methods for motivating them – in both open and closed contexts – are, however, poorly understood and therefore the fourth research question is defined as:

RQ4: How may managers motivate individuals towards radical innovation work?

In sum, four empirical studies have been conducted in large mature companies, each of which responds to one of four research questions. Theoretically, the

dissertation aims to contribute to the literature on radical innovation and open innovation by increasing understanding on the role of users and customers in developing radical innovations, the substitution of internal R&D with supplier innovations, the absorption of radical ideas from unusual sources, and motivational issues in radical innovation development. Each of the empirical studies provides a complementary viewpoint to the research problem of how incumbent companies may develop radical innovations in open innovation settings. The contributions of these studies are combined in this compiling part of the dissertation.

The rest of the dissertation is structured as follows. In section 2, literature on the management of radical innovations is reviewed. Then, in section 3, the view on radical innovation is extended by discussing how open innovation may help companies develop radical innovations. These sections position the dissertation in the relevant innovation management literature. Then, in section 4, gaps in extant research are introduced and the theoretical motivations of the four research questions are discussed. In section 5, the methodological approach of the dissertation is described. The section starts with discussion on the philosophical foundations of this dissertation. Then, case study research design and its various forms are introduced. Next, the adopted principles of case selection, data collection, and analysis in all four empirical studies are discussed. Then, the methods to ensure the validity and reliability of the research are presented. Section 6 presents the main findings of the empirical studies and thus answers the research questions. The section is structured according to the four research questions. In section 7, the theoretical contributions of the studies to the innovation management literature are discussed and their practical implications for managers are presented. Furthermore, the limitations of the dissertation are addressed and avenues for further research are suggested. Finally, section 8 summarizes the study.

2. Radical innovation and its management

Following Fagerberg (2005), innovations are here defined as successful new products, services, methods of production, exploitation of new markets, or ways to organize business. Innovations are distinguished from inventions, which refer to new ideas for innovations. Innovation is therefore considered the outcome of a successful implementation of an invention. This is, however, not the only meaning that the concept of innovation has. Innovation is generally understood both as the process of successful application of new ideas and the outcome of such process (Dodgson et al., 2014). Innovative outcomes result from development activities and both a new product and creating such product — the noun and the verb — can be called innovation.

Innovation management is a discipline which studies the factors that affect the occurrence of innovation in organizations: sources, strategies, and practices (Dodgson et al., 2014). It is an applied field, strongly driven by a variety of practical concerns, and consequently it draws from multiple theories with their underpinnings in sociology, economics, and psychology. Related topics in the management literature include the management of research and development (R&D), which addresses the systematic use of scientific and engineering knowledge to achieve practical results (Trott, 2005). Another topic is new product development (NPD), which concerns the management of various organizational functions in creating new products (Trott, 2005). Both of these can be understood as subsets of innovation management. Taking a wider perspective, innovation management can be understood as a part of the field of innovation studies, which also includes research on sectoral, regional, and national innovation systems and the economics of R&D (Fagerberg et al., 2012).

What follows is an account of extant literature on radical innovation. Radical innovation will be defined, and its origins and benefits explained. Then, managerial challenges associated with the development of radical innovations are discussed paying particular attention to different forms of uncertainty related to radical innovations. Next, methods to overcome these challenges are discussed from the viewpoints of processes, organizational structures, and culture.

2.1 Innovations of varying novelty

Innovations can be classified according to their novelty. When innovations are modest in novelty and include only small advances in terms of technology, features, or performance, they are called *incremental*. Incremental innovations provide improvements to existing technology in the existing market (Garcia & Calantone, 2002). *Radical* innovations, on the other hand, involve novel knowledge bases, technologies, and markets, which generate new growth opportunities and unforeseen features (Tellis et al., 2009). In addition to incremental and radical, there are a variety of related classifications and definitions which characterize the nature and novelty of innovations (Table 1).

As can be seen from the table, there are multiple ways to classify innovations. All of the definitions address novelty and change in some respect: there are innovations that are modest in terms of novelty and introduce relatively minor change and there are innovations which have the capacity to create paradigm shifts in the technology and market structures (Garcia & Calantone, 2002). Often, many of the high-novelty innovations are referred to as radical innovations. Competence-enhancing, competence-destroying, discontinuous, disruptive, and even architectural innovations tend to be characterized as radical. This impreciseness in the use of concepts has downsides as it is not always clear which type of novelty a radical innovation is associated with: significant leaps in existing technologies and products, new products, new markets, new business models etc. It has been proposed that different categories, such as radical product innovations, disruptive technologies, and disruptive business models, follow a similar processes to invade existing markets but have different managerial implications, which suggests a need to differentiate between them (Markides, 2006).

Distinguishing between different forms of highly novel innovations is, however, tricky. In general, assessments of an innovation's type may be conducted *ex ante* that is before market introduction and *ex post*: after market introduction. Many of the *ex post* definitions emphasize the impact of an innovation as a way to define its novelty. Tushman & Anderson (1986) propose that innovations may be classified according to the impact they have on the competences of existing firms in an industry: they may be competence-enhancing or competence-destroying. The concept of disruptive innovation refers to innovations which introduce a new set of performance attributes which initially satisfy only a niche market segment but in time mature enough to invade the mainstream market (Christensen, 1997; Danneels, 2004; Govindarajan et al., 2011). Other definitions address impacts on market infrastructures (Garcia & Calantone, 2002) and changes in customer behaviour (Veryzer, 1998). In addition, Dahlin & Behrens (2005) propose that to determine an innovation's radicalness, its influence on the content of future inventions should be evaluated.

Table 1. Definitions of innovation types with varying novelty¹.

Concept	Definition
Radical innovation (Ettlie et al., 1984)	Technology that is new to the adopting unit and new to the referent group of organizations, or requires both throughput (process) and output (production or service) change, or requires a significant or costly change of the organization.
Radical innovation (Green et al., 1995)	Innovation that is associated with technological uncertainty, technical inexperience, business inexperience, and technology cost.
Radical innovation (Garcia & Calantone, 2002)	Innovations that embody a new technology and result in a new market infrastructure at the world, market or industry level.
Really new innovation (Garcia & Calantone, 2002)	Innovations that embody a new technology or result in a new market infrastructure at the world, market or industry level.
Incremental innovation (Garcia & Calantone, 2002)	Products that provide new features, benefits, or improvements to the existing technology in the existing market.
Discontinuous innovation (Veryzer, 1998)	Radically new products that involve dramatic leaps in terms of customer familiarity and use.
Discontinuous innovation (Rice et al., 1998)	A "game changer" which has the potential: (1) for a 5–10 times improvement in performance compared to existing products; (2) to create the basis for 30–50 percent reduction in cost; or (3) to have new-to-the-world performance features.
Discontinuous innovation (Birkinshaw et al., 2007)	The implementation of new technologies, products, or business models that represent a dramatic departure from the current state of the art in the industry.
Breakthrough innovation (O'Connor & Rice, 2001)	Innovations with have the potential to "change the game" from the developing company's perspective.
Disruptive innovation (Christensen, 1997)	Technologies which surpass seemingly superior technologies in the market. ²
Competence-destroying innovation (Tushman & Anderson, 1986)	Innovation which creates a new product class or substitutes for an existing product and destroys the competence of existing firms in an industry.
Competence-enhancing innovation (Tushman & Anderson, 1986)	Order-of-magnitude improvements in price/performance that build on existing know-how within a product class.
Radical innovation (Henderson & Clark, 1990)	Establishes a new dominant design and, hence, a new set of core design concepts embodied in components that are linked together in a new architecture.
Architectural innovation (Henderson & Clark, 1990)	Innovation that changes a product's architecture but leaves the components, and the core design concepts that they embody, unchanged.
Modular innovation (Henderson & Clark, 1990)	Innovation that changes the core design concepts of a technology but leaves the product's architecture intact.
Incremental innovation (Henderson & Clark, 1990)	Introduces relatively minor changes to the existing product, exploits the potential of the established design, and often reinforces the dominance of established firms.

The boundaries between some of these impact-based definitions are, however, sometimes blurry. As an example, both competence-destroying innovations and disruptive innovations are likely to undermine incumbent firms' competences within an industry (Danneels, 2004), and they might both be considered as types of radical innovation (Govindarajan et al., 2011). Moreover, it is suggested that also incremental innovations can be classified into competence-enhancing and competence-destroying categories (Gatignon et al., 2002), which would mean that these characterizations are not exclusive to radical innovation.

Ex ante definitions focus on the characteristics of the innovations and the aims of the developers. Many authors have focused on technological novelty in defining whether an invention is radical or incremental: is the technology significantly different from existing technologies (Ettlie et al., 1984; Garcia & Calantone, 2002)? It has been suggested that an invention may be considered radical if it is dissimilar from prior inventions, and unique: dissimilar from current inventions (Dahlin & Behrens, 2005). Novelty can also be found in a

¹ For a more comprehensive review of innovation types, see Augsdörfer et al. (2013).

² This compact summary of the key ideas of Clayton Christensen's book is adopted from Markides (2006).

product's design. Henderson & Clark (1990) propose that to be counted radical an innovation needs to change both a product's architecture and the design of its individual components. Interestingly, some authors refer to the aims of the developers when defining innovations. The influential radical innovation research group at the Rensselaer Polytechnic Institute suggests that radical innovation can be defined *ex ante* by its potential for achieving significant impacts (Leifer et al., 2000; O'Connor & Rice, 2001; Rice et al., 1998). As the potential has not yet been realized, researchers may rely on the developing companies' assessments in identifying radical inventions and radical innovation projects (Rice et al., 1998). Along the same lines, Govindarajan et al. (2011) propose that the defining feature of disruptive innovations is that they target emerging customer segments instead of mainstream customers. They hence propose that the aims related to target markets can be used to identify disruptive innovations. They also propose that high technological novelty is not a necessary requirement for disruptive innovation. Therefore, some disruptive innovations are radical also in a technical sense and some radical innovations are disruptive in that they target emerging market segments. Disruptive innovation can thus be considered a subset of radical innovation.

From a developing company's point of view, *ex post* definitions may be useful for picturing the potential impact of future innovations and classifying past projects, but *ex ante* definitions may be more helpful in understanding the differences between various kinds of development processes and consequently in informing managers who are responsible of their development. For the purposes of this dissertation, radical innovations are here defined as *products, services, or processes which encompass novel technologies or require new market structures, and which have the potential to create paradigm shifts at the world, market, or industry level*. They therefore cover the categories of radical innovation and really new innovation as proposed by Garcia and Calantone (2002). This is mainly an *ex ante* definition as it describes radical innovations in terms of technological novelty and their potential market impact. Similarly to the radical innovation research group at the Rensselaer Polytechnic Institute, the identification of radical innovations in this dissertation relies on expert evaluations in the developing companies. Naturally, *ex ante* evaluations are complemented with *ex post* evaluations when possible, for example by looking at the market impact of past innovation projects. O'Connor (2008) has previously named innovations of this scope major innovations, but that name is not used very widely. The definition is relatively broad and inclusive as it does not require the innovations to have both high technological novelty and require new market structures. Ticking just one of these boxes will suffice. Therefore, certain disruptive innovations with low technological novelty are included as long as their potential is evaluated high. Similarly, radical technologies targeted at existing markets are counted. Neither does the definition distinguish between competence-enhancing and competence-destroying innovations. While there are studies which suggest that it is more difficult for incumbent companies to target emerging than existing markets (Christensen & Bower, 1996; Christensen & Rosenbloom, 1995) and that it may be more demanding for them to introduce

competence-destroying than competence-enhancing innovations (Maine & Garnsey, 2006), a case can be made that this level of analysis has its merits. Innovations which are truly novel in terms of both technology and market structures and have high potential are extremely rare. Instead, companies often seek to develop high-potential innovations and find that to do that they need to explore new technologies or identify new market segments, sometimes even both. O'Connor (2008) points out that the difference between radical and really new innovations is one of degree: for radical innovations, the uncertainties may be even more extreme or exist in more dimensions. In contrast, the difference between these two types and incremental innovation is more fundamental. Therefore, it is often practical to treat the former innovation types characterized with high uncertainty together and contrast them with incremental innovation. This is also supported by a Sandberg & Aarikka-Stenroos (2014) who find that barriers to the development of innovations are significantly different between radical and incremental innovations, but there are no major differences between the barriers of radical innovations with different degrees of novelty. This suggests that it is possible to provide managerial insights on how to develop high-potential innovations in situations where new technological and/or market spaces are explored (Bessant et al., 2014).

2.2 Triggers and benefits of radical innovation

The emergence of radical innovations has been linked to the wider industry context. Technological development has been noted to advance according to trajectories (Nelson & Winter, 1982) that are defined by commonly shared ideas about which problems are relevant and what kind of knowledge should be sought to solve them (Dosi, 1982). Incremental innovations are likely to emerge in the kind of situations where the goals and problem-solving methods are clear and the main focus is on increasing productivity (Utterback & Abernathy, 1975).

Every now and then, something happens that shakes this balance and provides opportunities for more novel approaches. These triggers of discontinuity (Table 2) may make existing trajectories unavailable or challenge established ways of thinking. New challenges emerge that do not fit the existing schemas according to which organizations focus their attentional and operational resources (Bessant et al., 2014). External changes and their incompatibility with companies' prior experiences and ways of thinking trigger turbulent, "fluid" phases of exploration in a new technological or market space before new product designs and market conditions are stabilized (Anderson & Tushman, 1990; Bessant, 2008; Tushman & Anderson, 1986; Utterback & Abernathy, 1975). In these phases, firms need to be able to step out of their comfort zone and transform themselves by developing novel products and services (Tushman & O'Reilly, 1996). In such situations, companies often do not fight only over the share of current markets, but also over emerging new markets (Martin & Mitchell, 1998). The more discontinuities the companies face, the more opportunities and pressure they have for developing radical innovations.

Table 2. Triggers of discontinuity, adapted from Bessant et al. (2005, pp. 1639–1640).

Triggers of discontinuity	Explanation
New market emerges	Most markets evolve through a process of growth, segmentation, etc. But at certain times, completely new markets emerge which cannot be analysed or predicted in advance or explored using conventional market research/ analytical techniques.
New technology emerges	Step change takes place in product or process technology — may result from convergence and maturing of several streams (e.g., industrial automation, mobile phones) or as a result of a single breakthrough (e.g., LED as white light source)
New political rules emerge	Political conditions which shape the economic and social rules may shift dramatically, for example, the collapse of communism meant an alternative model — capitalist competition, as opposed to central planning — and many ex-state firms couldn't adapt their ways of thinking.
Running out of road	Firms in mature industries may need to escape the constraints of diminishing space for product and process innovation and the increasing competition of industry structures by either exit or by radical reorientation of their business.
Sea change in market sentiment or behaviour	Public opinion or behaviour shifts slowly and then tips over into a new model — for example, the music industry has undergone a (technology-enabled) revolution in delivery systems from buying records, tapes and CDs to direct download of tracks in MP3 and related formats.
Deregulation/shifts in regulatory regime	Political and market pressures lead to shifts in the regulatory framework and enable the emergence of a new set of rules — e.g., liberalization, privatization or deregulation, environmental legislation.
Fractures along 'fault lines'	Long-standing issues of concern to a minority accumulate momentum (sometimes through the action of pressure groups) and suddenly the system switches/ tips over — for example, social attitudes to smoking or health concerns about obesity levels and fast-food.
Unthinkable events	Unimagined and therefore not prepared for events which — sometimes literally — change the world and set up new rules of the game (e.g., 9/11).
Business model innovation	Established business models are challenged by a reframing, usually by a new entrant who redefines/reframes the problem and the consequent 'rules of the game' (e.g., Amazon).
Architectural Innovation	Changes at the system architecture level rewrite the rules of the game for those involved at the component level.
Shifts in 'techno-economic paradigm' — systemic changes which impact whole sectors or even whole societies	Change takes place at the system level, involving technology and market shifts. This involves the convergence of a number of trends which result in a paradigm shift where the old order is replaced (e.g., the Industrial Revolution).

The emergence of new development trajectories is often visualized in the form of S-curves (Figure 1). Plotted with “performance” and “time” axes, the evolution of (technological) innovation is noted to form a curve with an S-shape. This is because, initially, new technologies improve consumer benefits rapidly and later on more slowly when the technology matures (Foster, 1986). New technological breakthroughs enable the shaping of new technological trajectories, which may give rise to radical innovations if sufficient effort is put into their development (Chandy & Tellis, 1998). Often such radical innovations replace previous technologies in the markets because of their superior price-performance ratio. Garcia & Calantone (2002) emphasize that similar curves can be identified both for technical development and marketing, which reflects the two dimensions of novelty in radical innovations. While the S-curves provide an efficient way of illustrating the performance differences between old and new technologies, they have their limitations (Dahlin & Behrens, 2005). First, it is often nearly impossible to foresee which kind of development trajectory a recent innovation will generate, restricting S-curves to ex post identification of radical innovations. Second, the approach assumes that different technologies may be compared using the same performance

dimensions, which is not always true as radical innovations may generate new performance criteria, which is often the case with disruptive innovations (Danneels, 2004). Furthermore, S-curves typically illustrate the effects of competence-destroying innovations (Tushman & Anderson, 1986): a new product emerges which provides superior performance to an existing one and hence undermines competences related to the established product. In contrast, competence-enhancing innovations could be illustrated with a steep increase in the performance within an existing technological trajectory instead of a new curve.

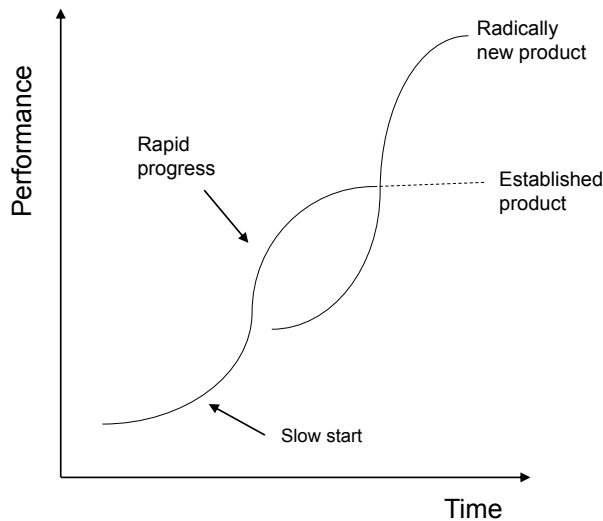


Figure 1. S-curves, adapted from Foster (1986) and Garcia & Calantone (2002).

Radical innovations have been suggested to have many beneficial outcomes for the developing firm, which is why they are proposed to be very attractive for companies to pursue. Radical innovations are often associated with high value creation (Tellis et al., 2009), cost reductions (Leifer et al., 2000), and profitability (Song & Montoya-Weiss, 1998). They are suggested to have the ability to fulfil customer needs in new ways (Chandy & Tellis, 1998) and generate new meanings and symbolic content for products (Verganti, 2008). Eventually, they may improve the developing firm's long-term growth and renewal (Leifer et al., 2001; McDermott & O'Connor, 2002), which results in increased financial performance (Coccia, 2016; Kyriakopoulos et al., 2016; Rubera & Kirca, 2012; Sorescu et al., 2003) and competitive advantage (O'Connor, 2008). While a vast amount of research suggests such positive outcomes, radical innovation should, however, not thought as a magic cure for all kinds of situations. First of all, the development of radical innovations can be very costly and take a long time (Leifer et al., 2000). Combined with the fact that their success rate tends to be very low, investments in radical innovation may as well have negative returns. Second, introducing competence-destroying innovations may be profitable as, for example, a new product line takes over

markets. At the same time, the introduction of such innovations is likely to lower the value of the company's existing resources and competences and decrease demand for its prior products (Maine & Garnsey, 2006). This kind of radical innovations, unlike most competence-enhancing innovations, destabilize incumbent companies, including the ones who introduce them (Gatignon et al., 2002). Third, some radical innovations, especially disruptive ones which target emerging markets, may initially address the needs of a small group of customers (Danneels, 2004). Before a radical innovation matures enough to break through from niches to the mainstream market, its benefits may remain modest, and this process may take a long time (Schot & Geels, 2007).

2.3 Managerial challenges associated with radical innovation

Despite their benefits, radical innovations of different types have been found difficult to develop. Radical innovation has been associated with requirements that differ substantially from those of incremental innovations (Bessant et al., 2005; Ettlie et al., 1984; O'Connor & DeMartino, 2006; O'Reilly & Tushman, 2008). Table 3 introduces some of the key differences between the management of radical and incremental innovations from several viewpoints. The differences presented in the table are generalizations of multiple studies and should be understood as "archetypes" (McLaughlin et al., 2008), rather than strict rules or definitions, but they nevertheless indicate major discrepancies between what is needed of an organization if it wishes to develop incremental compared to radical innovations.

Many authors refer to high levels of uncertainty when explaining why radical innovation requires particular management approaches. Uncertainty refers to situations where the outcomes of actions are not known (Melandar & Tell, 2014). In the case of high uncertainty, the probability of success of different actions may be impossible to evaluate (Knight, 2006). Uncertainty can also be considered as the difference between the amount of knowledge required to perform a certain task and the amount of knowledge already possessed (Mullins & Sutherland, 1998).

While some uncertainty is always associated with innovation, it has been proposed that different conditions of uncertainty may necessitate different approaches to innovation management (Bstieler, 2005). The novelty inherent in radical innovation brings about levels of uncertainty that are significantly higher than in incremental innovation (Cabrales et al., 2008; Kennedy et al., 2016; Song & Thieme, 2009). Radical innovation projects are often characterized by a lack of knowledge needed to finish them and by a limited understanding of what kind of knowledge would be valuable in the first place (Vanhaverbeke et al., 2003). Both the available options and the potential outcomes may be unknown in radical innovation development, which may create a context of "extreme" uncertainty (Packard et al., 2017). Uncertainty related to the development of innovations can take many forms. It can be related to technological aspects, markets, organization, resources, or social impacts (Hall & Martin, 2005; O'Connor & Rice, 2013a). Based on a review of the extant

literature, several dimensions of uncertainty are found to be relevant for radical innovation.

Table 3. Key differences between the management of radical and incremental innovations, adapted from McLaughling et al. (2008) (the first seven differences) and Leifer et al. (2000) (the last nine differences).

Dimension	Incremental	Radical
Procedures	Formalized, centralized, systematic	Contingent, decentralized, loosely structured
Structure	Functional, efficiency-oriented	Facilitating knowledge gathering, supporting risk taking and experimentation
People	Homogeneous, older and experienced	Heterogeneous, younger and entrepreneurial, technical, questioning
Organizational aspects	Mature, high inertia, focus on efficiency and team-working, continuous improvement	Entrepreneurial; focus on discovery; individual cooperation; frame-breaking improvement
Focus	Cost reduction, feature addition, efficiency improvement	New methods and technologies; experimentation; new ideas; creation
Products/ technologies	Mostly existing	Mostly new
Learning aims	Exploitation	Exploration
Project timeline	Short term: six months to two years	Long term: usually ten years or more
Trajectory	Linear and continuous path from concept to commercialization	Sporadic with many stops and starts. Trajectory changes in response to unanticipated events.
Idea generation and opportunity recognition	Occur at the front-end, critical events are largely anticipated	Occur throughout the project
Process	Formal approved process through all stages	Formal process has value only at the later stages
Business case	Prepared in detail at the beginning of the process	Evolves through discovery-based technical and market learning
Team	Cross-functional team with clearly specified individual responsibilities	"Cross-functional individuals" and large, informal networks
Organizational structures	Project team within a business unit	Starts in R&D, migrates into an incubation organization, and transitions into a project organization
Resources and competencies	Project team has sufficient skills for the project. Project is subject to standard resource allocation process	Creativity and skill in resource and competency acquisition from a variety of sources are critical for success
Operating unit involvement	Tight involved from the beginning	Loose informal involvement at early stages

Technological uncertainties are related to understanding the scientific basis of new technologies and their applications (Green et al., 1995). Often there are alternative technologies for achieving certain functionalities and managers need to choose between them. To make this decision, they need to be convinced of the technologies' feasibility (Lynn & Akgün, 1998). There may also be ambiguity about which technological features are important and how the specifications of new products should be determined (O'Connor & Rice, 2013a). Further uncertainty is related to finding the right approach to develop technologies towards selected goals and finding the best methods to manufacture the final product (Sheasley, 1999). Radical innovation projects often include working with new technologies which increases the level of technological uncertainty. The performance of the technologies may be hard to assess, and the evaluation of how quickly new products based on them can be developed may be difficult (Herrmann et al., 2007). Especially at the beginning of a radical project, it is almost impossible to foresee all the technical issues that should be considered (Chiesa et al., 2009). Therefore, technical specifications are difficult to set (Rice

et al., 2002). New technologies are also likely to demand changes in manufacturing, which brings about further uncertainties (Brettel et al., 2011).

Market uncertainties relate to estimating the future demand for innovations. A key issue in innovation management is deciding which ideas should be invested in and which should not. There may be many potential markets, value propositions, and business models from which to choose (O'Connor & Rice, 2013a). Managers may not be sure who the customers are and what they want (Jaworski & Kohli, 1993; Lynn & Akgün, 1998). Furthermore, the process of finding answers to these issues is challenging: which market analysis methods are likely to provide the most relevant information (O'Connor & Rice, 2013a)? Bringing highly novel products to the market or creating altogether new markets both imply high uncertainty about whether the customers will accept the innovation (Brettel et al., 2011; Ritala & Sainio, 2014). Customer requirements for the new product may be unclear (Herrmann et al., 2007) and conventional market research methods may be unsuitable (Frishammar et al., 2016). Hence, predicting the business impact is extremely challenging (Chiesa et al., 2009), even more so if the innovation is associated with new business models (Rice et al., 2002; Ritala & Sainio, 2014). Furthermore, innovations may produce unanticipated outcomes that may influence their acceptance and the reputation of the developing company. For example, in Brazil, innovations related to biofuel technologies have raised concerns over poor working conditions and environmental impacts (Hall et al., 2011).

There may also be *organizational and resource uncertainties*. They concern the management potential changes within innovation projects, tensions between the project teams and various project interfaces, and the availability of resources. Managers should be able to create and lead project teams which incorporate all the necessary capabilities for reaching the desired outcomes and finding suitable processes for putting them into practice (Fox et al., 1998). Often the team composition needs to be adjusted when the project advances. Another issue concerns the project's status within the organization. Changes and inconsistencies in expectations and commitment produce uncertainties of a project's future status (McLaughlin et al., 2008; O'Connor & Rice, 2013a). This issue may be critical if the project's budget and schedule are not nailed down (Huchzermeier & Loch, 2001). There should also be knowledge of which resources are needed for the development process, which are currently available, and how to acquire the missing ones (O'Connor & Rice, 2013a). Because of the high technological and market uncertainties, radical innovation is associated with high risk (Sorescu et al., 2003), which generates challenges related to how to deal with changes in management support and acquiring resources and competencies (Leifer et al., 2000; Rice et al., 2002). Obtaining continuous management support is difficult and radical innovation projects are often neglected or terminated before they are completed (Gassmann et al., 2012; Gemünden et al., 2007). Uncertainty about management support often goes together with uncertainty about funding and competencies for projects (Leifer et al., 2001). Incumbent companies, in particular, tend to prefer to initiate more certain projects (Kennedy et al., 2016) because, under high uncertainty, the

probability of making poor decisions is increased (Day, 1994) and it is easy to find arguments to play it safe and focus on incremental initiatives (Bessant et al., 2011).

As there is variety within the concept of radical innovation, the levels of the uncertainties and related managerial challenges are not the same across all radical innovation projects (O'Connor, 2008). Radical innovations which include novel technologies are naturally associated with higher technological uncertainty and those which target new markets will face higher market uncertainty. Some disruptive innovations, for example, may have relatively low technological uncertainty but very high market uncertainty (Govindarajan et al., 2011). Organizational and resource uncertainties are typically emphasized in competence-destroying innovations because such innovations will compete with companies' existing products and resources (Chandy & Tellis, 1998). It is easier to find support for the development of innovations which is compatible with a company's existing assets than for those that would make them dispensable. Despite of these differences, it can be argued that the development of radical innovations is associated with various managerial challenges related to technological, market, and/or organizational and resource uncertainties, and that the presence of these challenges is a key divider between the development of incremental and radical innovations.

2.4 Overcoming the challenges

Radical innovations are widely studied, which has resulted in extensive knowledge of the challenges related to their development and how companies can overcome them (Assink, 2006; O'Connor, 2008; Sandberg & Aarikka-Stenroos, 2014; Slater et al., 2014). The extant literature on what companies should do to increase their chances of introducing radical innovations has been categorized in different ways.

Chang et al. (2012) propose that companies need four capabilities to improve their radical innovation performance: 1) openness capability, 2) autonomy capability, 3) integration capability, and 4) experimentation capability. Openness capability refers to the ability to harvest ideas and competencies from a wide array of sources. Autonomy capability refers to the firm's ability to encourage and tolerate risky, ambiguous, unsuccessful radical ideas. Integration capability is about integrating and aligning radical innovation with the mainstream business. Finally, experimentation capability is the ability to probe, experiment with, test, and commercialize radical ideas and concepts, across R&D, manufacturing and marketing disciplines.

O'Connor (2008) proposes an alternative categorization and argues that a management system for radical innovation should include seven elements: 1) a clearly identified organizational structure, 2) internal and external linkages mechanisms, 3) exploratory processes, 4) requisite skills, 5) appropriate governance and decision-making mechanisms and criteria, 6) appropriate metrics, and 7) suitable cultural and leadership context.

Table 4. Managerial categories needed for the development of radical innovations.

Category	Definition	Related categories in the literature
Processes	Systematic ways of governing radical innovation projects from early idea stages to commercialization.	<ul style="list-style-type: none">• Experimentation capability (Chang et al., 2012)• Appropriate governance and decision-making mechanisms and criteria (O'Connor, 2008)• Appropriate metrics (O'Connor, 2008)• Suitable innovation processes (Slater et al., 2014)• Product launch strategy (Slater et al., 2014)
Organizational structures	The allocation of responsibilities and resources for radical innovation development within the organization and the integration of radical innovation development with other organizational functions.	<ul style="list-style-type: none">• Integration capability (Chang et al., 2012)• A clearly identified organizational structure (O'Connor, 2008)• Internal linkages (O'Connor, 2008)• Requisite skills (O'Connor, 2008)• Organizational characteristics (Slater et al., 2014)
Culture	Shared concepts, values, and beliefs within the organization that support radical innovation.	<ul style="list-style-type: none">• Autonomy capability (Chang et al., 2012)• Suitable cultural and leadership context (O'Connor, 2008)• Suitable organizational culture (Slater et al., 2014)• Senior leadership (Slater et al., 2014)
External linkages	Search for radical innovation opportunities from outside the organization.	<ul style="list-style-type: none">• Openness capability (Chang et al., 2012)• External linkages (O'Connor, 2008)• Organizational characteristics (Slater et al., 2014)

Slater et al. (2014) propose another set of components needed for the capability to develop radical innovations: 1) suitable innovation processes, 2) suitable organizational culture, 3) senior leadership, 4) organizational characteristics such as cross-functional integration, reliance on partners, and suitable structure, and 5) product launch strategy.

These categorizations have evident similarities, and for the purposes of this dissertation, these insights are combined to a set of four managerial categories that are proposed to be necessary for the development of radical innovations: processes, organizational structures, culture, and external linkages. Table 4 introduces these categories and illustrates their linkages to the categorizations in the extant literature. Next, the first three categories, processes, organizational structures, and culture are shortly introduced. Finally, the fourth category is reviewed in a separate section (section 3) with a more extensive discussion of external linkages under the concept of open innovation.

2.4.1 Processes

Formal process models, such as the widely diffused Stage-Gate systems (Cooper, 1990), rely on extensive planning so that the development process can be predicted and divided into discrete steps (Eisenhardt & Tabrizi, 1995). They have, however, been noted to be poorly suitable for radical innovations (Benner & Tushman, 2003; Veryzer, 1998). Because of the high uncertainties in radical innovation projects, such planning is extremely difficult, if not impossible. First of all, their development trajectories may be nonlinear and include unexpected changes of direction (Rice et al., 1998; Robbins & O'Gorman, 2015) and are

hence characterized by serendipity and chance (Godoe, 2000). Forcing them into linear process models may therefore be harmful. Second, especially when aiming for new markets, formal market analyses may provide misleading results, as the ultimate uses and relevant markets for radical ideas may be unknown (O'Connor & Rice, 2013a; Sandberg, 2008) or they may disrupt existing markets (Markides, 2006). Therefore, market size and customer behaviour are difficult to estimate (Kim & Wilemon, 2002; Verworn et al., 2008) and a focus on existing markets and customers may lead to underestimating their potential (O'Connor, 1998).

Instead, radical innovations are considered to benefit from rapid iterations and experimentations (Chang et al., 2012; Koberg et al., 2003; McGrath, 2001). By testing intermediate products in practice, for example by building prototypes and testing markets with early versions, companies may reduce both technological and market uncertainties and be better equipped to reframe the development targets for the next iteration rounds (Lynn et al., 1996). In practice, radical innovation projects often include many unanticipated obstacles and challenges (Alexander & van Knippenberg, 2014; Day, 1994) which make changes of direction necessary (Leifer et al., 2000). Since reliable data may not be available due to high uncertainties (Cooper, 2013), project managers need to rely on trial and error and situation-specific competencies instead of rigorous planning (O'Connor & DeMartino, 2006; Phillips et al., 2006).

O'Connor (2008) argues that the development of radical innovations cannot be reduced to sets of codifiable processes. It relies on boundary conditions and priorities instead of rigid processes and focuses on the continuous development of situation-specific knowledge instead of utilizing existing knowledge.

2.4.2 Organizational structures

As most incumbent companies strongly focus on incremental innovation, developing radical innovations at the same time may generate major tensions within the company and even paradoxical situations where different aims and methods are inherently incompatible (Andriopoulos & Lewis, 2009; O'Reilly & Tushman, 2004). Incumbents are typically found to have considerable organizational inertia which prevents them from adopting systems and processes which would allow them to seek and seize opportunities for radical innovations (Hill & Rothaermel, 2003; Teece, 2007). This is particularly true when a company seeks competence-destroying radical innovations as they often undermine the company's other objectives.

Because radical and incremental projects are found to have different goals and time scales (Leifer et al., 2000) and require different culture and procedures (McLaughlin et al., 2008), they are often in conflict with each other, which creates tensions (Andriopoulos & Lewis, 2009). Structural separation of radical and incremental development has been widely proposed as a solution (Chandy & Tellis, 2000; Herrmann et al., 2007; O'Connor, 2008; O'Connor & DeMartino, 2006; O'Reilly & Tushman, 2008; Slater et al., 2014). It is suggested that radical innovation activities should be separated from the mainstream organization by establishing dedicated organizational units such as a radical

innovation hub (Leifer et al., 2001), exploratory unit (O'Reilly & Tushman, 2008), corporate venturing program (Chesbrough, 2000), or independent business unit (Christensen & Raynor, 2003).

The units may take care of one or more of the following tasks: i) discovery of new opportunities and ideation, ii) cultivating ideas and experimenting with them, and iii) commercialization (Markovitch et al., 2015; O'Connor & Ayers, 2005). Sometimes separate units may be responsible for all the tasks, but more often the projects are integrated into business units at some point. While there is a wide support for such arrangements, there is some anecdotal evidence that they tend to be quite short-lived, lasting on average around five years (Hisrich & Peters, 1986; O'Connor & Ayers, 2005).

While structural separation may have benefits, it may not be needed in every case. McDermott & O'Connor (2002) report that radical innovation projects may sometimes find their home in existing business units. They suggest that such fit may be achieved if the projects do not threaten existing operations and if they do not pose significant financial burden to the business unit. Other authors suggest that with the right kind of leadership, conflicting goals may be strived for within the same business unit. If the context of the business unit is such that it is rich in support, trust, ambition, and commitment, it might be able to both be efficient in current business and seek radically new opportunities (Gibson & Birkinshaw, 2004). Such arrangements may also benefit from top management that works well together as a truly integrated team (Lubatkin et al., 2006).

When structural separation is implemented, radical projects should not be developed in isolation. Cross-functional and cross-disciplinary knowledge sharing and collaboration is argued to be one of the most important factors for successful outcomes from radical projects (Aagaard & Gertsen, 2011; Büschgens et al., 2013; Slater et al., 2014). Cross-functionality reduces conflicts and allows the efficient combination of diverse knowledge from many functions (Atuahene-Gima, 2005). Cross-functional interfaces may in fact be responsible for the success of radical innovation units, since they may facilitate the creation of informal ties and improve the operational business units' receptiveness to radical projects (Gassmann et al., 2012).

While cross-functional integration is typically treated as a one-dimensional variable in the literature, some have elaborated it in more detail. Brettel et al. (2011) point out that cross-functionality may take many forms. R&D may be connected with different functions, the integration may take place at different phases of the development process, and it may increase the effectiveness or efficiency of radical and incremental projects. They find that the R&D unit's integration with marketing and manufacturing is found especially important in the commercialization phase of radical projects. O'Connor (2008) remarks that the integration may consider i) roles, ii) strategy, iii) resources, networks, and administrative systems, or iv) learning processes. Therefore, it is not fully clear which kinds of integration across functions are optimal for different situations.

2.4.3 Culture

Organizational culture comprises shared concepts, values, and beliefs within an organization (Schein, 2010). The extant studies have suggested that a different kind of culture is needed for developing radical, rather than incremental, innovations. The optimal culture for radical innovation is suggested to have a long-term orientation (Herrmann et al., 2007), promote curiosity (Bessant et al., 2005) and thinking beyond what currently exists (McLaughlin et al., 2008), and to value entrepreneurship (Slater et al., 2014) and new ideas (Green & Cluley, 2014). A persistent obstacle in radical innovation development is that company members get attached to their current products and do not wish to replace them, even in the case of an inevitable decline in demand. Sunk investments and previous successes make managers unwilling to cannibalize their existing assets until it is too late (Assink, 2006). While it is, in a way, logical to avoid competing with the company's own products and services rather than those of competitors (Cravens et al., 2002), breakaway from current investments is often necessary for introducing new ones (Chandy & Tellis, 1998; Nijssen et al., 2005).

It has been suggested that radical innovation development requires the acceptance, or even encouragement, of risk taking (Herrmann et al., 2007; Kyriakopoulos et al., 2016). Radical innovation is inherently risky due to high uncertainties and significant unanticipated challenges throughout the development processes (Alexander & van Knippenberg, 2014). Risk-avoidance, which may be beneficial for incremental innovations, can be a significant barrier to radical innovations (Assink, 2006; McLaughlin et al., 2008). Since engaging in high-risk projects is bound to result in occasional failure, attitudes towards failure are important. Employees should not fear for their careers when proposing new ideas (Aagaard & Gertsen, 2011; Koen et al., 2005). In their study of radical innovation in incumbent US firms, O'Connor and McDermott (2004, p. 24) were told that "The origin of the breakthrough success is often forgotten, but an R&D effort that does not succeed is never forgotten." Hence, rewards and risks in participating in radical projects should be in balance (Burgelman, 1985; Leifer et al., 2001).

In general, radical innovation seems to be poorly suitable with bureaucracy and formality which are likely to decrease creativity and risk taking (Benner & Tushman, 2003; Ekvall, 1997; Martinsuo & Poskela, 2011). Instead, high autonomy for the development teams is proposed to benefit it (Chiu et al., 2016; Leifer et al., 2000). To increase the performance of the developers, managers should give them room for experimentation and allow them to challenge existing strategy (Hill & Rothaermel, 2003; Reid & de Brentani, 2004).

3. Openness and radical innovation

The last of the four radical innovation management categories discussed in the previous chapter was about the external linkages of companies. The utilization of external linkages for innovation has been studied under the concept of open innovation (Chesbrough, 2003). In the following pages, the idea of open innovation and its relation to radical innovation are introduced.

3.1 What is open innovation?

In recent years, researchers have responded with growing interest to the question of how to leverage the innovation potential outside the boundaries of the focal firm (Brem, 2010; Gassmann et al., 2010; West & Bogers, 2014). Since the seminal book by Henry Chesbrough in 2003, the utilization of external sources for innovation has been studied under the concept of *open innovation*. Chesbrough (2003, p. xxiv) defines open innovation as “a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology.” In 2006, a new definition that emphasizes inter-organizational knowledge flows was proposed by Chesbrough et al. (2006, p. 1). According to them, open innovation can be understood as “the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively.” Chesbrough and Bogers (2014, p. 17) link business models to open innovation when they define it as “a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization’s business model.” Finally, Lichtenthaler (2011, p. 77) emphasizes different knowledge activities and uses a definition according to which open innovation is “systematically performing knowledge exploration, retention, and exploitation inside and outside an organization’s boundaries throughout the innovation process.” What is common for all these definitions is that they emphasize connections that span the boundaries of the focal company and their benefits for innovation.

Open innovation is by no means a new phenomenon, neither in academia nor in practice. Companies have collaborated for a long time before the publication of Chesbrough’s book in 2003 and academics have studied related phenomena, such as the not-invented-here syndrome (Katz & Allen, 1982), complementary

assets (Teece, 1986), absorptive capacity (Cohen & Levinthal, 1990), inter-organizational knowledge sharing (Dyer & Nobeoka, 2000), technology sourcing (Veugelers, 1997), and R&D spillovers (Audretsch & Vivarelli, 1996). Open innovation has emerged as an umbrella concept which brings together a variety of related discussions.

Extant studies have reported of a significant number of different partners that companies collaborate with for innovation. Among the most important ones are customers (Cohen et al., 2002; Fang et al., 2008; Wong et al., 2016), users (Baldwin & von Hippel, 2011; Bogers et al., 2010; Chatterji & Fabrizio, 2014; Schemmann et al., 2016), suppliers (Song & Di Benedetto, 2008; Wagner & Bode, 2014; Winter & Lasch, 2016), and universities (Laursen & Salter, 2004; Perkmann & Walsh, 2007; Veugelers & Cassiman, 2005; Walsh et al., 2016). Other parties that have been addressed include competitors (Ritala & Sainio, 2014), consultants (Bianchi et al., 2016), research centres (Tether & Tajar, 2008), and public institutions (Pilav-Velić & Marjanovic, 2016). Also, the innovation potential of communities has gained attention (Fleming & Waguespack, 2007; Füller et al., 2007; Levine & Prietula, 2013; Martinez-Torres & Olmedilla, 2016), especially in the context of open source software (Belenzon & Schankerman, 2015; Dahlander & Magnusson, 2005; Henkel, 2006; O'Mahony & Bechky, 2008; von Krogh et al., 2003).

Studies on open innovation have increased at a rapid rate in the recent years (Randhawa et al., 2016) and open innovation practices have been reported as having diffused to more companies (Chesbrough & Crowther, 2006) and being used more intensively than before (Chesbrough & Brunswicker, 2014). This has been explained by the fact that many high-tech companies have undergone major changes in how they do research, moving from a closed and introverted paradigm to an extroverted, open one (Christensen et al., 2005). Also, the major trends of globalization, technology intensity, technology fusion, new business models, shorter innovation cycles, increasing industrial R&D costs, high product modularity, and the scarcity of the required resources have been argued to increase the benefits from openness (Enkel & Gassmann, 2008; Gassmann et al., 2006; Geum et al., 2013). As products, processes, and services become increasingly complex, companies need to rely more on external resources in developing innovations (Bercovitz & Feldman, 2007; Chesbrough, 2003).

If companies are too internally focused, they may miss opportunities for innovation (Laursen & Salter, 2006). According to the literature, the benefits of open innovation are extensive. Adopting open innovation practices may facilitate different phases of the innovation process: problem identification (Dahlander & Piezunka, 2014), front-end (Thanasopon et al., 2016), idea generation and selection (King & Lakhani, 2013; Schemmann et al., 2016), solution finding (Dahlander & Piezunka, 2014), and commercialization (Walsh et al., 2016). These benefits are reflected in performance improvements at the level of the R&D function (Cassiman & Valentini, 2016; Cheng & Shiu, 2015; Chiesa et al., 2009; Laursen & Salter, 2006). Open innovation may increase R&D productivity by providing cost and time savings (Chesbrough, 2007) and innovation quality (Cheng & Huizingh, 2014; Laursen & Salter, 2006; Walsh et

al., 2016), boosting both its efficiency and effectiveness (Alexy et al., 2016), and is thus likely to lead to enhanced new product success (Cheng & Huizingh, 2014; Rohrbeck et al., 2009), project financial performance (Du et al., 2014), and more attractive sales figures from new products (Love et al., 2014).

At the company level, open innovation is associated with profitability (Noh, 2015), stock value (Noh, 2015), decreased production costs (Noh, 2015), increased sales volume (Noh, 2015), new revenues (Chesbrough, 2007), financial performance (Cheng & Huizingh, 2014; Sisodiya et al., 2013), overall firm performance (Hung & Chou, 2013), and the ability to adapt to changing market conditions (Dittrich & Duysters, 2007). Open innovation may also improve customer satisfaction and loyalty (Cheng & Huizingh, 2014; Wagner, 2010).

Open innovation can take several different forms reflected in the arrows in Figure 2. Gassman & Enkel (2004) propose that the variety of different open innovation arrangements can be described with three main archetypes: inbound (or outside-in), outbound (or inside-out), and coupled processes. Inbound processes refer to the ability to acquire knowledge from external sources, whereas outbound processes consist of activities where the focal firm uses external partners to exploit internally generated knowledge, i.e., by the means of licensing out, selling, or spin-offs (Cheng & Huizingh, 2014). In coupled processes, both the creation and exploitation of new knowledge is conducted in collaboration with one or more external partner. Such joint development and commercialization arrangements can occur, for example, in joint ventures or alliances (Cheng & Huizingh, 2014).

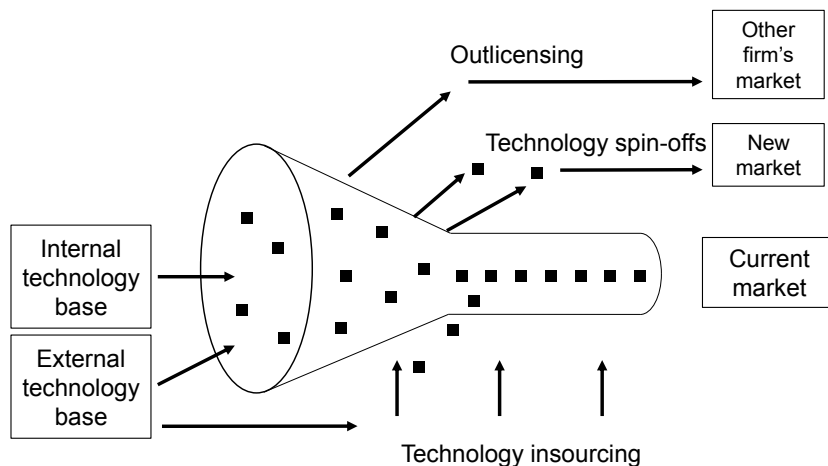


Figure 2. Open innovation processes, adapted from Chesbrough (2012).

Open innovation is often understood as collaboration between two parties. It can, however, take forms beyond traditional dyadic relationships, within triads (Chesbrough & Appleyard, 2007), value chains (Zobel et al., 2016), networks (Pittaway et al., 2004), and ecosystems (van der Borgh et al., 2012). Dahlander and Gann (2010) point out that not all knowledge needs to be paid for. Some

relevant knowledge is bound to be available through market mechanisms, e.g., by licensing. However, often companies may have free access to external knowledge based on their relationships with other companies. In other cases, knowledge may be made freely available to all (Huizingh, 2011). Examples of such knowledge include basic research conducted by universities (Perkmann & Walsh, 2007) and open-source software (von Hippel & von Krogh, 2003).

3.2 How can open innovation benefit radical innovation?

Previously, it has been argued that many of the challenges associated with radical innovation arise from a high level of uncertainty. Taking this assumption as a starting point, open innovation can be analysed based on its ability to reduce uncertainties. Many authors point out that when development teams face technological uncertainty, they tend to react by seeking external knowledge (Kim et al., 2015). Ritala & Sainio (2014) propose that, because radical innovations are so risky and uncertain they require extensive usage of different types of external relationships. Partnerships may hence be used to reduce risk and in multiple dimensions (Bessant et al., 2010; Lettl, 2007; McDermott, 1999). Radical innovations may also have significant social impacts that are hard to predict (Hall & Martin, 2005) and communication with different stakeholders may help in this. According to Bessant et al. (2014), radical innovation takes place in a complex and highly uncertain search and selection space, where the market needs coevolve with stakeholders. They suggest that the optimal strategy in such environments is to work with new and diverse networks to be receptive to weak signals and access a range of different knowledge bases. High uncertainty is hence associated with a more open approach to innovation (Gianiodis et al., 2010). If firms face a lot of obstacles in their development processes, they are more likely to value collaboration and look for established solutions from other industries (Barge-Gil, 2010; Enkel et al., 2009). Indeed, many types of openness have been proposed to be beneficial for radical innovation: participating in industrial networks, inviting experts to predict the future, and cooperation with universities and research centres to develop new ideas (Chang et al., 2012). The integration of external knowledge is considered to help companies break free of path-dependency and hence enable radical innovation (Coombs & Hull, 1998) as open innovation practices may expand a company's view of market and technology opportunities and help them to execute tasks within the radical innovation processes (Zang et al., 2014).

There is empirical evidence for the proposition that firms which intensively source new knowledge and technologies from external partners will be more likely to introduce radical product innovations (Knudsen et al., 2017) and process innovations (Pilav-Velić & Marjanovic, 2016). The logic behind these benefits is that a single company is unlikely to be able to develop all the capabilities required for radical innovation (Geffen & Rothenberg, 2000). Therefore, many radical innovation projects make use of other's technology development efforts (Kelley et al., 2013) and capabilities (Kim et al., 2015), by e.g. relying on joint ventures, mergers and acquisitions, and alliances (Stringer,

2000). Open innovation practices may also reduce the risk associated with radical innovation, as collaborative ventures often include risk-sharing agreements between the parties (Kennedy et al., 2016). There are, however, also some findings which suggest that the uncertainties related to radical innovation might reduce the benefits of some forms of open innovation. Collaboration with competitors, for example, is found to suffer from risks of knowledge leakages and opportunism, which may be especially harmful in the case of radical innovation (Bouncken et al., 2017; Ritala & Sainio, 2014).

3.3 Challenges associated with open innovation

While open innovation may help reduce technical and market uncertainties it may bring about its own challenges. Enkel et al. (2009) report that 43% of the companies that they studied have difficulties in finding the right open innovation partners. 48% of the same set of companies identified high coordination costs as a risk that hinders them from benefiting from open innovation. According to Chesbrough (2003), adopting open innovation practices requires significant organizational changes in companies. Moving from closed to open innovation requires changes in how external relationships are managed and how external knowledge is integrated into internal development processes. Due to the complexity in making this transition, not all companies are able to reap the benefits that open innovation has to offer (Chesbrough & Brunswicker, 2014; Gassmann et al., 2010). Next, three challenges related to the management of open innovation are presented to provide background for the remaining research questions of the dissertation which address the use of open innovation to promote radical innovation: 1) evaluating potential partners and their knowledge, 2) transferring and integrating external knowledge, 3) managing collaborative relationships.

First, acquiring valuable knowledge from external sources is difficult because companies have limited means to evaluate the new technologies and opportunities that are generated externally (Chiaroni et al., 2010; Hu et al., 2015). Many open innovation endeavours are bound to fail (Lopez-Vega et al., 2016; Love et al., 2014) or advance very slowly (Wallin & Von Krogh, 2010; Wong et al., 2016) because of the difficulties in detecting and transferring valuable knowledge. First, there is the challenge of choosing the right knowledge sources. Partnerships with suppliers, customers, universities, and competitors are an efficient way to gain access to external knowledge (Un et al., 2010). Choosing the best partners for open innovation is, however, difficult, since there is high uncertainty of their competencies – especially so if no previous collaboration has taken place (Badir & O'Connor, 2015; Enkel et al., 2009; Laursen & Salter, 2006). There is likely to be considerable information asymmetry about the capabilities of the potential partners, which makes it difficult to predict the outcomes of open innovation collaborations (Saebi & Foss, 2015). Also, within existing partnerships there may be difficulties in locating relevant knowledge as there needs to be understanding about “who knows what and where critical expertise resides within each firm” (Dyer &

Singh, 1998, p. 665). Therefore, it is suggested that companies should develop capabilities to evaluate external innovation sources and the value of external knowledge and technologies (Cassiman & Valentini, 2016; Winter & Lasch, 2016).

In addition to locating and evaluating external knowledge, it needs to be transferred and integrated within the organization (Kogut & Zander, 1992). This may be challenging as the knowledge that is sought for may vary in where it resides and how it may be transmitted. A key distinction which helps understand the management of relevant knowledge in an open innovation is that between explicit knowledge and tacit knowledge setting (Nonaka & Takeuchi, 1995; Polanyi, 1967). While explicit knowledge is transmittable in formal, systematic language, such as text, tacit knowledge entails action, commitment, and involvement (Nonaka, 1994; Polanyi, 1967). Tacit knowledge may reside in individuals' plans, skills, and habits, or collectively in the firm's culture, past collaborative experiences, and routines (Cavusgil et al., 2003; Inkpen & Dinur, 1998). It is acquired by means of personal experience and is difficult to express and observe, whereas explicit knowledge may be observed, articulated, and documented in formal language, print, and electronic media (Inkpen & Dinur, 1998; Smith, 2001). Due to these differences, particular attention should be paid to the methods that can be used to codify, store, transfer, and apply different kinds of knowledge in organizations (Alavi & Leidner, 2001; Davenport & Prusak, 1998). If a company is unable to transfer and utilize explicit and tacit knowledge from its partners, collaborative innovation activities are likely to result in modest outcomes (Azadegan, 2011; Colombo et al., 2011; Roy et al., 2004; Sjoerdsma & van Weele, 2015).

Finally, companies must learn to manage their open innovation relationships. For example, in joint development projects, it is challenging to evaluate if the other party puts in the maximum effort and there is considerable risk of opportunism (Lakemond et al., 2016; Oxley & Sampson, 2004). Especially in highly innovative projects, precise project goals cannot always be defined in advance (Kloyer & Scholderer, 2012) and to manage the partners' opportunistic behaviour, companies often invest in promoting trust in the relationship (Lawson et al., 2009; Ragatz et al., 1997) or in monitoring the other parties' behaviour (Melander et al., 2014; Oxley & Sampson, 2004). Another issue considers decisions about intellectual property that may result from the collaboration. The literature is somewhat conflicted in how important it is to protect new knowledge, for example by patents, in an open innovation setting (Laursen & Salter, 2014). On the one hand, opening up to external partners for value creation may have the downside of spillovers of valuable knowledge, which weakens the company's ability to capture value (Arora et al., 2016). Strong intellectual property rights are hence often considered necessary when adopting open innovation practices (Chesbrough, 2003; West, 2006). In technology-intensive industries, there is evidence that patenting may actually increase the subsequent number of open innovation relationships of new entrants (Zobel et al., 2016). On the other hand, some authors argue that companies are overly protective of their knowledge (Laursen & Salter, 2014).

Protecting internal knowledge may limit knowledge exchange and enforcing protective measures can be quite costly (Baldwin & von Hippel, 2011). Some companies have, in fact, started to reveal some of their intellectual property to increase the overall development pace in the field (Henkel, 2006), which might eventually turn out to be beneficial for their business (Henkel et al., 2014). In addition, companies should pay attention to the alignment of goals and expectations in the relationship (Fliess & Becker, 2006; Yan & Dooley, 2013). Conflicts are likely due to the inherent nature of collaborative development (O'Sullivan, 2006) and mechanisms should be established for managing potential disagreements (Blome et al., 2013; Lam et al., 2007; Wu & Wu, 2015).

3.4 Absorptive capacity

It is proposed that for open innovation activities to result in better innovation performance, organizational learning capabilities are needed (Cheng & Shiu, 2015). Perhaps the most studied of such capabilities is *absorptive* capacity, which is defined as the “ability to identify, assimilate, and exploit knowledge from the environment” (Cohen & Levinthal, 1989, p. 589), and is considered a key construct for explaining the success of inbound open innovation activities. It is a competence which enables the access to and benefits from knowledge, ideas, and technologies from external sources (Christensen et al., 2005). Therefore, it can be used to explain how some organizations are able to benefit from external knowledge sources better than others. Absorptive capacity fits well with the overall idea of open innovation (Lichtenthaler & Lichtenthaler, 2009) and it has been linked to open innovation performance in multiple studies (Bianchi et al., 2016; Enkel & Gassmann, 2008; Randhawa et al., 2016; Saebi & Foss, 2015; West & Bogers, 2014). Investigations into absorptive capacity may increase understanding about how companies are able to respond to the challenges of identifying and evaluating new opportunities, and transferring and integrating external knowledge, and hence turn the potential of operating in an open environment into increased innovation performance.

Originally, Cohen and Levinthal (1989, 1990), who formulated the theory, considered absorptive capacity to be a byproduct of internal R&D investments. According to them, internal R&D, not only creates new knowledge but also improves an organization's ability to assimilate and exploit existing knowledge. The connection between absorptive capacity and internal R&D has been so strong that the level of absorptive capacity has frequently been measured by looking at measures such as a company's R&D expenditures or R&D intensity (Bianchi et al., 2016; Lane & Lubatkin, 1998; Rothaermel & Alexandre, 2008; Stock et al., 2001; Tsai, 2001). The reasoning behind this is that internal R&D efforts are considered to enhance the learning capacity of the members of an organization (Cohen & Levinthal, 1990). If the individuals within an organization have wide knowledge bases, it is easier for them to understand various kinds of new knowledge (Cohen & Levinthal, 1990). Prior related knowledge can therefore lower the costs of recognizing and acquiring new knowledge and increase the organization's ability to understand and apply it

(Cohen & Levinthal, 1990; Lenox & King, 2004). Moreover, internal R&D work enhances employees' problem-solving and learning skills. These factors help employees make novel associations and relate new knowledge to what they already know (Cohen & Levinthal, 1990). These associations between a company's existing knowledge base and its ability to absorb new knowledge have led researchers to assume that openness may complement internal R&D, but that internal R&D cannot be replaced by external inputs (Dahlander & Gann, 2010).

A major advance in the development of the concept of absorptive capacity was the identification of sub-capabilities of absorptive capacity which resulted in a more nuanced process view of how the absorption process takes place (Zahra & George, 2002). Today, absorptive capacity is typically conceptualized by dividing it into four sub-capabilities: acquisition, assimilation, transformation, and exploitation (Todorova & Durisin, 2007; Volberda et al., 2010; Zahra & George, 2002) as illustrated in Figure 3. *Acquisition* refers to identifying and gaining access to external knowledge and may vary according to speed, intensity, and direction (Zahra & George, 2002). If an organisation's search scope is limited, it is unable to benefit from many knowledge sources. Acquisition capability reflects openness towards the environment of a company (Camisón & Forés, 2010) and its ability to detect new opportunities (Noblet et al., 2011).

After acquisition, new knowledge has to be analysed, processed, interpreted, and understood, that is, *assimilated*. Companies with high assimilation capability can successfully leverage their employees' knowledge, experience, and competency for integrating new ideas and discoveries (Forés & Camisón, 2016). Often, the acquired knowledge challenges existing ways of thinking (Noblet et al., 2011) and the organization's existing knowledge base needs to be adjusted or reinterpreted to ensure compatibility (Forés & Camisón, 2016). *Transformation* capability addresses this process of combining new knowledge with existing knowledge structures. There is some debate about whether assimilation and transformation are both necessary elements of absorptive capacity (Zahra & George, 2002) or actually alternatives. Todorova & Durisin (2007) propose that when new knowledge fits into existing cognitive structures well enough, it can be assimilated, but that transformation is needed when the knowledge sets are incompatible to the extent that new cognitive structures have to be built via combination.

Finally, *exploitation* stands for the incorporation of the new knowledge into the company's operations (Zahra & George, 2002). The outcomes of exploitation may be, for example, patents (Camisón & Forés, 2010; Forés & Camisón, 2016), new products (Todorova & Durisin, 2007), or the achievement of other organizational goals (Noblet et al., 2011).

Zahra & George (2002) further distinguish between potential absorptive capacity and realized absorptive capacity. Potential absorptive capacity is about being receptive to acquiring and assimilating new knowledge, whereas realized absorptive capacity concerns the transformation and exploitation of the assimilated knowledge. Imbalance between these two explains how a company

may have significant knowledge base (high potential absorptive capacity) without any performance increase (low realized absorptive capacity). New knowledge has to be exploited, for example by developing new product innovations, to reap the benefits.

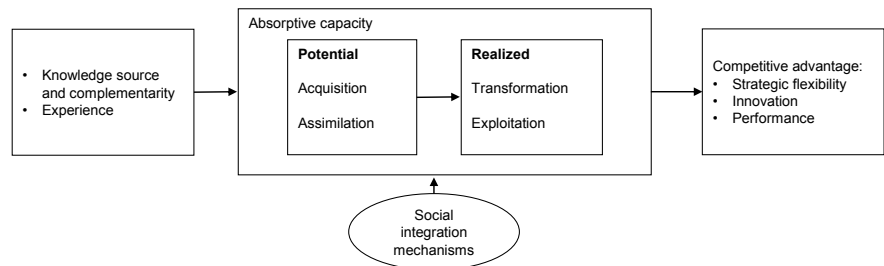


Figure 3. Absorptive capacity model. Modified from Zahra & George (2002).

Besides individual-level absorptive capacities, mechanisms to ensure knowledge flows within the company are needed to develop organizational-level absorptive capacity (Cohen & Levinthal, 1990). Zahra & George (2002) propose social integration mechanisms to work towards this purpose. They describe social integration mechanisms as formal and informal mechanisms which enhance sharing and integrating new knowledge within the organization by overcoming barriers to knowledge flows and facilitating interactions among the organizational members. Van den Bosch et al. (1999) divide social integration mechanisms into three categories: coordination mechanisms, socialisation mechanisms, and systems mechanisms. Table 5 reviews extant studies on social integration mechanisms and their effects on absorptive capacity capabilities.

Socialisation mechanisms facilitate the creation of common codes of communication and reduce the amount of conflicting goals within a group (Jansen et al., 2005) by specifying tacit rules for appropriate action and structuring social experiences (Van den Bosch et al., 1999). Teaching new employees unit-specific languages, values, beliefs, and norms creates strong links between them which facilitates communication and comprehension and reduces conflicts (Jansen et al., 2005; Lewin et al., 2010). Connectedness, that is the density of networks, is noted to govern interactions within the organization (Jansen et al., 2005). Strong and extensive ties within a specific group promote the creation of trust, improve cooperation, and facilitate knowledge exchange (Ebers & Maurer, 2014; Jansen et al., 2005; Todorova & Durisin, 2007). Despite of their benefits, socialisation mechanisms may also sometimes inhibit absorptive capacity as they increase reliance on a specific set of knowledge sources which may result in myopia and inertia due to “group think” (Jansen et al., 2005; March, 1991; van Lancker et al., 2016).

Coordination mechanisms facilitate knowledge transfer between organizational members across disciplinary and hierarchical borders (Jansen et al., 2005). Communication interfaces connect employees and increase the scope of knowledge absorption since individuals with various backgrounds and expertise can be utilised. They also help integrate new knowledge into existing knowledge bases, create shared interpretations of problems, and overcome

differences. Cross-functional interfaces also facilitate decision making and help develop commitment that is needed in implementing new knowledge. The role of well-connected and socially adept individuals in linking acquired and assimilated knowledge to those who can transform and exploit it has been recently acknowledged (Ebers & Maurer, 2014; Jones, 2006; Tortoriello, 2015). Gatekeepers, boundary spanners, and change agents may promote formal and informal communication across and within companies and drive changes at the levels of organization, routines, and strategy (Jones, 2006).

Table 5. Social integration mechanisms.

Category	Social integration mechanism	Absorptive capacity capability
Socialisation mechanisms	Connectedness (Jansen et al., 2005)	Assimilation, transformation, exploitation
	Connectedness (Roberts, 2015; Todorova & Durisin, 2007)	Acquisition, assimilation, transformation, exploitation
	Social networks (Todorova & Durisin, 2007)	Acquisition, assimilation, transformation, exploitation
	Social networks (Zahra & George, 2002)	Assimilation, transformation
	Trust and strong ties (Ebers & Maurer, 2014)	Acquisition, assimilation, transformation, exploitation
	Shared values and norms (Lewin et al., 2010)	Acquisition, assimilation, transformation, exploitation
	Unit-specific language, values, and beliefs (Jansen et al., 2005)	Transformation, exploitation
Coordination mechanisms	Formal social integration mechanisms, e.g. organizational structures, coordinators (Zahra & George, 2002)	Assimilation, transformation
	Structures and routines for knowledge transfer (Matusik & Heeley, 2005)	Acquisition, assimilation
	Informal hall talk, cross-functional communication (Roberts, 2015)	Not defined
	Cross-functional interfaces and job rotation (Jansen et al., 2005)	Acquisition, assimilation, transformation
	Participation in decision making (Jansen et al., 2005)	Acquisition, transformation
	Relational learning (e.g. knowledge sharing routines, joint teams, face-to-face meetings) (Leal-Rodríguez et al., 2014)	Linking potential absorptive capacity (acquisition and assimilation) and realised absorptive capacity (transformation and exploitation)
	Cross-functional interactions, participatory leadership (Hotho et al., 2012)	Not defined
	Boundary spanners (Ebers & Maurer, 2014)	Acquisition, assimilation, transformation, exploitation
	Boundary spanners (Tortoriello, 2015)	Not defined
	Gatekeepers and boundary spanners (Jones, 2006)	Acquisition, assimilation
	Change agents (Jones, 2006)	Transformation, exploitation
Systems mechanisms	Formalisation (Jansen et al., 2005)	Transformation, exploitation
	Routinisation (Jansen et al., 2005)	(Negative effects) acquisition, assimilation, transformation
	Data integration (Roberts, 2015)	Acquisition, assimilation, transformation, exploitation
	Information systems capabilities (Cepeda-Carrion et al., 2012)	Linking potential absorptive capacity and realised absorptive capacity

Finally, systems mechanisms such as manuals, policies, and procedures are formal and explicit methods to control organizational behaviour. They provide organizational memory for handling recurring events and establish patterns of organizational action (Jansen et al., 2005). Formalisation, routinisation, and the use of information systems may facilitate the knowledge flows and help maintain a consistent view of the firm's knowledge base (Cepeda-Carrion et al., 2012; Jansen et al., 2005; Roberts, 2015). Systems mechanisms may, however,

have some downsides as codified rules do not allow changes of plans when new unexpected ideas or events arise (Jansen et al., 2005).

The value of connecting the absorptive capacity construct to the open innovation literature is in that it provides a general framework that can be used to assess an organization's readiness for open innovation. By investigating the four capabilities and social integration mechanisms, it is possible to analyse how a company is able to find, integrate, and use external knowledge for innovation.

4. Research gaps

In the following sections, four specific areas of interest, within the topic of using open innovation to promote radical innovation, are introduced for the purpose of motivating the four research questions in this dissertation.

4.1 Gap 1: Customers and users in radical innovation

One of the most active research streams which draws from both radical innovation and open innovation literatures investigates whether interacting with customers and users is beneficial for radical innovation or not. Despite of the vast amount of research that has been conducted, opposing views persist (Agostini et al., 2016; Nicholas et al., 2015).

According to one group of studies, customers and users are important sources of ideas and knowledge about market needs for radical innovation (e.g. Chatterji & Fabrizio, 2014; Lettl et al., 2006). This is a very logical position considering that the benefits of interacting with customers and users for the development of products, services, and processes have been reported over several decades (Cavaye, 1995; Gassmann et al., 2006; Markus & Mao, 2004; von Hippel, 1976). These interactions have been considered very important for reducing market uncertainties (Martinez-Torres & Olmedilla, 2016). Customers and users may have insight into which product characteristics are the most important, what the market size is, and which factors influence consumer demand (Chatterji & Fabrizio, 2014). A strong user perspective and a deep understanding of user needs are considered especially valuable in the early stages of the innovation process, when most of the design decisions are still open (Schemmann et al., 2016). Strong orientation towards customers and users may also increase companies' priority placed on radical innovation as learning from them may induce a shift away from imitating their competitors (Baker & Sinkula, 2007).

The issue is, however, not so straightforward. There are studies which find suggest that customer and user involvement may actually be harmful for radical innovation (Kohli & Jaworski, 1990; Menguc et al., 2014; O'Connor, 1998). These results may arise from the fact that most customers and users are too familiar with existing products to be able to vision radically new ones (Enkel et al., 2005). Consequently, they might not be able to assess the value of radical ideas, which may give the developing companies misleading signals (Nicholas et al., 2015).

To solve this discrepancy, several explanations have been proposed. Lettl et al. (2006) argue that companies tend to give users only a passive role, such as involving them in the evaluation of new concepts or prototypes that the companies have developed. They propose that in order to be valuable for radical innovation, users should be treated as active contributors of new ideas and concepts. This is, however, often difficult due to companies' poor ability to integrate external inputs in their innovation processes (Katz & Allen, 1982).

It has also been proposed that companies focus too strongly on their customers' and users' expressed needs and disregard their latent needs (Sandberg, 2007). Latent needs are defined as the needs of which a customer or user is unaware of; needs which are not in their consciousness (Narver et al., 2004). They cannot be articulated and therefore alternative methods should be used to learn from them (Slater & Narver, 1998). Such methods may include such as applied ethnography and emphatic design (Janssen & Dankbaar, 2008; Verganti, 2008). The logic is that by understanding the latent needs of their customers and users, companies may pursue future market opportunities that are not evident to their competitors (Slater et al., 2014).

A third explanation considers the type of customers and users that are chosen. Von Hippel (1986, p. 796) writes that "the related real-world experience of ordinary users is often rendered obsolete by the time a product is developed or during the time of its projected commercial lifetime." What he calls ordinary users may therefore be of little use for radical innovation. Instead, *lead users* are proposed as an important source of insights for radical ideas or even prototypes of new products. Lead users are users whose present needs will become mainstream in the future and who would benefit significantly by obtaining a solution to those needs (von Hippel, 1986). They have been suggested to be valuable for radical innovation as they may recognize the relevance of new solutions earlier than their peers or the innovating companies themselves (Lettl et al., 2006, 2008; von Hippel, 1986). Along the same lines, it is suggested that for disruptive innovations companies should be interested in small but emerging customer segments whose needs will become mainstream in the future (Govindarajan et al., 2011; Yu & Hang, 2010).

A major shortcoming of the extant research is that it rarely distinguishes between customers and users. It is very common that authors use the terms interchangeably within a same study (Callahan & Lasry, 2004; Fuchs & Schreier, 2011; Kaulio, 1998; Nijssen et al., 2012; Sánchez-González et al., 2009). This may reflect a focus on consumer markets: a consumer who buys, for example, a bicycle is likely to be the one who ends up riding it. This is, however, not always the case. There are studies which address what Bogers et al. (2010, p. 859) refer to as *intermediate users*: "users such as firms that use equipment and components from producers to produce goods and services." Such intermediate users include physicians (Chatterji & Fabrizio, 2014), surgeons (Lettl, 2007), library staff (Morrison et al., 2000), firms that use machine tools (Lee, 1996), and construction companies (Slaughter, 1993). Here lies a danger since the the process of involving a cyclist is likely to be significantly different to

collaborating with machining shops and insights from one context may not be transferable to significantly different ones.

The difference between customers and users becomes apparent when thinking of large manufacturing companies operating in B2B environments. For companies that build and innovate complex products such as ships, airplanes, or power plants, customers and users are two distinct entities. The customer organizations typically have purchasing departments which are involved in making such major purchasing decisions in conjunction with top management (Van Weele, 2010). The ones who use the products (e.g. ship captains, airplane staff, and power plant operators) are often distinct from customers who make the purchasing decisions.

Recently, new digital technologies such as sensors, radio-frequency identification tags, and cloud computing have diffused into B2B manufacturing industries. This diffusion can be understood as a trigger of discontinuity (Bessant et al., 2005) that creates opportunities for radical innovation (Nylén & Holmström, 2015; Yoo et al., 2012). The digital technologies may be embedded in existing non-digital products and services to provide them new properties which may result in significant benefits for the developing company and major restructurings of entire industries (Nambisan et al., 2017; Nylén & Holmström, 2015; Yoo, 2010, 2013). The literature refers to these new combinations of digital and physical components as *digital innovations* (Yoo et al., 2010). B2B manufacturing industries, which are affected by the diffusion of digital technologies, provide a good setting to study differences between the contributions of customers and users to companies' radical innovation processes for two reasons: i) the industry setting is associated with opportunities for radical innovation, and ii) it emphasizes the difference between customers and users. The research opportunities provided by such a context and the gaps in earlier research considering the potential of customers and users for radical innovation motivate the first research question of this dissertation:

RQ1: How do B2B manufacturing firms leverage customers and users for the purposes of radical digital innovation?

4.2 Gap 2: Requirements for the level of internal R&D

The dominant view within the open innovation literature is that companies may use external knowledge sources to complement their internal R&D (Dahlander & Gann, 2010). This implies that in order to benefit from inbound open innovation companies need to make significant investments in internal innovation activities (Hung & Chou, 2013). This view is strongly influenced by the studies on absorptive capacity as they suggest that internal R&D not only helps companies generate new innovations by themselves but also facilitates their exploration and exploitation of new knowledge from outside the firm's borders (Cohen & Levinthal, 1989, 1990). Investing in internal R&D creates absorptive capacity which in turn promotes inbound open innovation (Bianchi

et al., 2016; Enkel & Gassmann, 2008; Randhawa et al., 2016; Saebi & Foss, 2015; Veugelers, 1997; West & Bogers, 2014).

It is proposed that understanding the ideas and technologies of the other party is not possible without some overlap in competences and knowledge bases (Hung & Chou, 2013; Mowery et al., 1996; Nooteboom et al., 2007).

If intensive internal R&D is a necessary condition for leveraging external sources of innovation, the open innovation paradigm, as stated by Chesbrough (2003), faces severe limitations. It is suggested that drawing too strongly from external knowledge sources should be considered as a weakness as it may limit an organisation's ability to explore new knowledge domains (Kim et al., 2016). Neglecting internal R&D may also eventually lead to the diminish of the company's core competences (Rothaermel & Alexandre, 2008). This line of thought suggests that companies with low internal R&D intensity are poorly able to benefit from openness.

At the same time, there are studies which suggest that collaboration for innovation would be particularly important for companies with low R&D intensity³ (Barge-Gil, 2010). It is quite straightforward to assume that companies which are lacking resources needed for innovation have the greatest need for external resources (Bayona et al., 2001). In the same fashion, companies which already have high technological proficiency may have less need for forming innovation networks (Pittaway et al., 2004). While high R&D investments and the resulting absorptive capacity may increase the benefits from collaboration it also enables companies to assimilate and use freely available knowledge which may lower their incentives to collaborate (Abramovsky et al., 2009).

Given the potential value of inbound open innovation for companies with low R&D intensity, the question of whether (and how) such companies may substitute their internal R&D efforts with inbound open innovation has been surprisingly poorly studied (Dahlander & Gann, 2010; Tanskanen et al., 2017). The open innovation literature has mostly focused on high-tech industries where high investments in internal R&D are common (Vanhaverbeke et al., 2014). Of the few studies on low-tech industries, Chesbrough & Crowther (2006) present preliminary evidence on that companies which start adopting open innovation practices maintain or increase their R&D investments, which suggests that they do not use open innovation to replace internal R&D. Spithoven et al. (2011) find that companies, which lack absorptive capacity, may still benefit from inbound open innovation with the help of technology intermediaries. This suggests that companies with low R&D intensity might be able to find alternative ways to engage in inbound open innovation.

While there is a lot of evidence which suggests that significant internal R&D investments are important for absorptive capacity and inbound open innovation, due to the limited number of studies which investigate low R&D contexts, it can be argued that the question of whether and how open innovation can replace internal R&D is still unresolved (Dahlander and Gann, 2010). In investigating these questions, the absorptive capacity model is likely to prove

³ R&D intensity refers to the company's R&D expenditure divided by its sales.

useful as it is one of the standard models on how external knowledge may be turned into innovations. The literature suggests that the four capabilities of absorptive capacity – acquisition, assimilation, transformation, and exploitation – are necessary for the absorption process to succeed (Zahra & George, 2002). Thus, examining those four capabilities may be helpful in analysing how the substitution of internal R&D with external knowledge may take place.

For many companies suppliers are the most important source of innovative technologies (Ellis et al., 2012; Un et al., 2010). Among potential open innovation partners, suppliers are particularly attractive as they are often familiar with their customers' needs, and they occupy a position where mechanisms for knowledge transfer are may be already in place (Un et al., 2010). Collaboration with suppliers has also been noted to benefit companies' radical innovation development (Phillips et al., 2006; Song & Di Benedetto, 2008). This has generated an active research stream which addresses the innovation potential of suppliers and methods for tapping into supplier innovations (Brem, 2010; Sjoerdsma & van Weele, 2015; Wagner, 2012; Yan et al., 2017). Concentrating on the context of suppliers provides a good opportunity for providing findings that are applicable to a specific domain. The lack of research of the absorption processes of supplier innovations in low R&D intensity motivates the second research question of this dissertation:

RQ2: How do the capabilities of acquisition, assimilation, transformation, and exploitation manifest themselves in substituting internal R&D with supplier innovations?

4.3 Gap 3: Extending to new idea sources

In order to introduce radical innovations, companies need to be able to acquire radical ideas and develop them (Cooper, 2013; Frishammar et al., 2016; Sergeeva, 2016). While such ideas may emerge from within a company, many seek also externally generated ideas that they may further develop and commercialize internally (Chesbrough, 2003). It is suggested that to ensure the acquisition of radical ideas, in particular, companies should collaborate with a wide range of different partners. Birkinshaw et al. (2007) argue that incumbent companies often have a stable set of partners that are focused on improving existing systems, rather than innovating radically new ones. In time, the diversity of knowledge embedded in the partner network is likely to diminish, which reduces its innovation potential (Dyer & Nobeoka, 2000). Too similar partners may hence limit the scope of the search for new opportunities by reducing differentiation, which may be harmful for radical innovation (Cui et al., 2015; Day & Schoemaker, 2004; Yan & Dooley, 2013). Furthermore, it may be difficult to break out of existing networks and establish new ones, which is considered a significant barrier for radical innovation (Birkinshaw et al., 2007).

The majority of the extant studies suggest that radical innovation requires a broad and explorative search for a variety of knowledge inputs that can then be

combined (Laursen, 2012; Zang et al., 2014). Since over-reliance on internal R&D and trusted and geographically close partners may lead to an emphasis on incremental innovation (Birkinshaw et al., 2007; Bunduchi, 2013; Chang et al., 2012; Stringer, 2000), experimenting with new partners is suggested as a best practice. This basic idea has been repeated in many forms in the extant literature. There are suggestions that companies should develop peripheral vision (Day & Schoemaker, 2004) and weak ties (Phillips et al., 2006), reach out beyond current relationships (O'Connor & McDermott, 2004), combine over multiple knowledge domains (Schoenmakers & Duysters, 2010), increase search breadth (Cai et al., 2014), and foster linkages with heterogeneous populations (Bessant et al., 2005).

Obtaining radical ideas from external parties and developing them into market-ready products is, however, not without challenges. First, the properties of radical ideas make them difficult to develop for many companies. Incumbent companies typically have mechanisms in place which make them favour incremental ideas over radical ones (Bessant et al., 2005; Chang et al., 2012; O'Reilly & Tushman, 2008). As radical ideas tend to be highly creative and original, they may challenge existing power dynamics and vested interests within organizations which may manifest in opposition to them (Ekvall, 1997; Lempiala, 2010; Magnusson, 2009; Sijbom et al., 2015). Furthermore, radical ideas may be difficult to comprehend and evaluate, which often leads to their rejection (Bessant et al., 2014, 2011; Ekvall, 1997; O'Connor & Rice, 2013b; Sandberg & Aarikka-Stenroos, 2014).

Secondly, companies often suffer from the not-invented-here syndrome (Antons & Piller, 2015; Cohen & Levinthal, 1990; de Araújo Burcharth et al., 2014; Katz & Allen, 1982), i.e. the tendency to reject external ideas and knowledge. The combination of these two challenges that arise from the radicalness of an idea, on the one hand, and the external source of an idea, on the other, may create a particularly demanding situation which may prevent companies from following the recommendations to promote their radical innovation by collaborating with new partners. Radical ideas are uncertain to start with and if they originate from unfamiliar sources they may be perceived as even more risky (Chesbrough, 2006). The context where radical ideas are acquired from unusual idea sources is, however, poorly understood as there is an absence of studies that focus on it.

The literature on absorptive capacity suggests that the integration and exploitation of ideas can be investigated by looking at social integration mechanisms which facilitate knowledge sharing and utilization within an organization (Jansen et al., 2005; Todorova & Durisin, 2007; Zahra & George, 2002). This approach is well in line with observations according to which radical innovation (Aagaard & Gertsen, 2011; Büschgens et al., 2013; Slater et al., 2014) and open innovation (Chiaroni et al., 2010; Foss et al., 2011) both benefit from well-working knowledge exchange systems within companies. To provide more understanding on the integration challenges that companies face when processing radical ideas from new kind of partners, the third research questions is defined as follows:

RQ3: How social integration mechanisms influence the absorption of radical ideas from unusual sources?

4.4 Gap 4: Individual motivation towards radical innovation development

The extant literature on radical innovation quite rarely analyses the effects of managerial actions at the level of individuals, and when it does, the issue of employee motivation is often completely missing. There are, however, reasons to believe that enhancing and maintaining individual motivation is particularly crucial when developing radical innovations.

First of all, based on the radical innovation literature, it is known that there might be differences between incremental and radical innovations with respect to their origins. The seed of incremental innovations are suggested to originate top-down from internal strategy processes (Koen et al., 2005; Reid & de Brentani, 2004) or alternatively by gathering feedback from customers (Leifer et al., 2000). It has been proposed that radical ideas flow bottom-up in the organization: they are generated by individuals, move upward to small groups and then proceed to project-level (Reid & de Brentani, 2004). Top management becomes aware of them typically only after project formalization. The bottom-up approach which promotes radical ideas and their development is therefore highly driven by the initiative of individuals (Benner & Tushman, 2003; Day, 1994; Leifer et al., 2000).

A proposed explanation for the pronounced role of individuals in radical innovation development is that process management methods which are commonplace in incremental innovation development are of limited use due to the high uncertainties associated with radical innovations (Benner & Tushman, 2003; O'Connor, 2008). Consequently, it has been suggested that when developing radical innovations managerial control should be eased and employees should be trusted to work on their own initiative quite freely (Alexander & van Knippenberg, 2014; Hill & Rothaermel, 2003; Koen et al., 2005; McCarthy et al., 2006; McGrath, 2001; Poskela & Martinsuo, 2009).

While it is often possible to identify highly motivated individuals that have managed to make use of their freedom behind successful radical innovations (Chakrabarti, 1974; Ettlie et al., 1984; Reid & de Brentani, 2004), their high levels of motivation are typically taken as granted and little attention has been paid to what motivates the developers and how managers could enhance and maintain their motivation (Poskela & Martinsuo, 2009). Radical innovation developers are often described as highly motivated, suitable for self-directed work and independent (Assink, 2006; Kelley et al., 2011; O'Connor & DeMartino, 2006) but it would be simplistic to assume that every developer working with radical innovations has superior intrinsic motivation which can be unleashed by reducing managerial control.

In fact, there are arguments which suggest that maintaining motivation in radical innovation development may be remarkably challenging. Due to high

uncertainties, the employees need to work in a demanding environment where they need to endure ambiguous situations and decision-making tasks, navigate across diverse knowledge bases and still be able to propose creative ideas and solutions (Bessant et al., 2005; Day, 1994). Furthermore, unanticipated obstacles and challenges that are prevalent in radical innovation projects may be detrimental to their motivation (Alexander & van Knippenberg, 2014). Due to these challenges it is no surprise to find that several studies have identified lack of motivation as a key obstacle to radical innovation and emphasized the need to manage it (Alexander & van Knippenberg, 2014; Kelley et al., 2011; O'Connor & McDermott, 2004; Stringer, 2000). If there is an absence of individual motivation towards radical innovation development, the organization is likely to be unable to generate radical innovations internally or benefit from external inputs to its innovation processes. Methods for enhancing and sustaining motivation towards radical innovation are, however, poorly understood. To fill this gap in the research, the following research question is defined.

RQ4: How may managers motivate individuals towards radical innovation work?

While this research question does not focus on challenges that open innovation specifically poses to radical innovation management, it was deemed important to include as individual motivation is a critical enabler of radical innovation, and this viewpoint has been largely ignored in both closed and open treatments of radical innovation.

5. Methodology

The purpose of this section is to explain how the four studies that comprise the empirical part of this dissertation are conducted and why certain methodological choices have been made. The section begins with discussion about the philosophical considerations that characterize the research. Next, the case study research design is presented. Then, the individual studies are described and related to the overall research questions of the dissertation. Finally, the general data collection and analysis methods in use as well as methods to increase validity and reliability of the findings are reviewed.

5.1 Ontological and epistemological foundations

Conducting research always means adopting philosophical positions in terms of the nature of reality (ontology) and knowledge (epistemology). It is often argued that to be able to generate new understanding about social phenomena, there needs to be some idea of what the reality is like and how it is possible to acquire knowledge of it (Searle, 2008; Tsoukas & Chia, 2011). In practice, these questions are not always thought out thoroughly, but are instead implicitly assumed when following well-known research designs and methods. It can, however, be argued that to properly understand the implications and limitations of one's research efforts, the philosophical foundations should be elaborated and made known at least to oneself.

In the social sciences, and management studies particularly, there are four⁴ common philosophical positions which are associated with certain ontological and epistemological assumptions (Christ, 2013; Lincoln et al., 2011; Martela, 2015; Miller & Tsang, 2011; Tsang, 2016; Tsoukas & Knudsen, 2005; Wicks & Freeman, 1998). These positions are positivism, critical realism, constructivism, and pragmatism, of which the last is adopted in this dissertation. Next, these positions are briefly introduced and the reasoning behind the adoption of pragmatism is clarified.

A key ontological dispute considers *realism*, that is, whether scientific theories and their concepts — including such things as atoms, viruses, values, competitive advantages, and knowledge transfer — describe entities that exist independently of the researcher or not (Devitt, 2008). Positivists and critical realists accept realism, which argues that the entities that theories discuss are

⁴ This is by no means an exhaustive list of available positions. See, for example, Tsoukas & Knudsen (2005) and Point et al. (2016) for further information.

objective parts of reality even though some of them cannot be directly observed, and that their existence is not dependent on anyone's mental items, ideas, or sense data (Devitt, 2008). The aim of realist scientific inquiry is therefore to produce true and accurate descriptions of the world (Chakravartty, 2016; Martela, 2015).

5.1.1 Positivism

Positivism and critical realism differ in their views of the researchers' ability to acquire knowledge about reality. Positivists assert that there are scientific laws, resembling those in natural sciences, that determine how organizations operate, and that these laws generally hold in all situations (Donaldson, 1996). Researchers are neutral observers who, using systematic methods, may find these laws. They may formulate hypotheses and collect objective data to test them (Wicks & Freeman, 1998) with the aim of achieving close correspondence between theory and reality (Boisot & McKelvey, 2010; Welch et al., 2011). Social sciences often address entities that are related to the "inter-subjective worlds" of the studied actors, for example organizational values and inner motivations of managers (Johnson & Duberley, 2015). Traditionally, positivism has excluded these interpretative entities as not belonging to proper science. The more recent versions (Glaser & Strauss, 2009) accept these social elements as a focus of social science research but maintain that the researchers are able to study these inter-subjective worlds objectively given proper research designs and methods (Glaser, 2002; Johnson & Duberley, 2015). Researchers often have biases but they may undertake rigorous measures to increase the validity and reliability of their findings (Gibbert et al., 2002; Winter, 2000). This way, their findings may be used to make generalizations about a larger population or theory (Welch et al., 2011).

5.1.2 Constructivism

Anti-realists, such as constructivists⁵, argue that the entities that theories describe do not exist independently. Instead, they are dependent on the cognitive activities and capacities of the researchers (Devitt, 2008). The reality is therefore not an object of neutral observation but constructed by the researchers that impose concepts and worldviews on it. Constructivists therefore argue in favour of subjectivity in science arising from values, languages, and politics (Tsang, 2016). Because subjective elements influence the way reality is constructed, there are bound to be multiple alternative realities. The goal for social sciences is to understand these realities and interpret them from the research subjects' own frames of reference (Tsang, 2016). Furthermore, researchers do not only examine the realities of their research subjects. Their own past experiences, beliefs, biases, gender and historical and sociocultural setting also influence the results (Jonassen, 1991; Longino, 1990; Phillips, 1995). Data resulting from scientific inquiry is therefore considered to

⁵ There are also moderate forms of constructivism that are compatible with realism (Kwan & Tsang, 2001).

be produced from the interaction between the researcher and the researched (Charmaz, 1995; Christ, 2013). There are hence no claims of objectivity and the aim for the research is to create informative representations of individual realities that might also be valuable in other contexts and empower marginalized voices (Christ, 2013; Hanson & Grimmer, 2007; Johnson & Duberley, 2015; Lincoln & Guba, 1985; Phillips, 1995). Whether there is an objective reality beyond all the interpretations remains unknown (Lincoln & Guba, 1985).

A common criticism against the anti-realist constructionist position is that if the existence of independent reality is questioned, the epistemological status of research outcomes becomes unclear (Johnson & Duberley, 2015). If there is no objective reality that is the source of our observations, it makes no sense to talk about the truth of theories (Boisot & McKelvey, 2010). What could then be the basis for ranking competing theories and explaining scientific progress? Is the only option to settle for all interpretations being equal?

5.1.3 Critical realism

Critical realists, as the name would suggest, accept realism but, compared to positivists, are more sceptical of the researchers' abilities to derive general laws that explain empirical observations (Bhaskar, 1998). It is based on the idea that knowledge of the world is always bound to be fallible and theory-laden (Sayer, 1992). They agree with the constructivists on that social phenomena are shaped by interpretation, but maintain that theories do, to a large extent, describe something that is independent of the researcher (Sayer, 1992). According to critical realism, experiences are the immediate object of researchers' observations (Bhaskar, 2008). To provide structure to the experiences, they are framed as events (Elder-Vass, 2007). For example, based on geocentric and heliocentric cosmological models, it is possible to construe two different events based on the experience of sunrise: either it's the movement of the sun, or the rotation of the earth (Bhaskar, 2008). Through experimental activity, researchers may identify patterns of events, and ultimately gain understanding on the underlying mechanisms which form the basis of causal laws, which are about "things, not events" (Bhaskar, 2008, p. 41). Moving between the levels of observations, events, and mechanisms requires interpretation (Easton, 2010). The "real" world may not be directly observable but it is, in the end, connected to the levels of events and observations (Easton, 2010; Johnson & Duberley, 2015). While scientific theories may not be able to depict reality in all of its complexity, they may provide quite accurate guides to the way processes work and produce particular outcomes (Ackroyd, 2010). Gradually, the science as a whole is likely to approach truth, as more data is collected by a community of diverse researchers and the best theories are identified among the alternatives (Easton, 2010).

Realist positions can be criticized on the grounds of under-determination. It can be argued that for every set of empirical evidence for a theory, an alternative theory can be found that is supported by it (Devitt, 2008). We may find theories that are at odds with each other but that are both supported by the same data

(Quine, 1970). Realists therefore need to clarify how theories should be prioritized if looking at the empirical evidence is not sufficient. If it cannot be argued that some theories are more true than others, how should scientific progress be evaluated? Furthermore, according to the so-called Duhem-Quine thesis, theories can never be tested in isolation. Instead, they are inseparable from auxiliary hypotheses such as background assumptions, methodological arguments, and theories on scientific instruments (Harding, 2012; Stanford, 2016). Even if a piece of evidence emerges that is incompatible with a specific theory, we cannot be sure if that is the weakness of the theory itself or of some auxiliary hypothesis. Accepting these arguments leads to a difficult position: despite the assumption of an independent reality, there seems to be no easy way to evaluate the merits of scientific theories based on their objective truth (Martela, 2015). Consequently, it becomes unclear what difference it makes for scientific inquiry whether we accept realism or not. While realism perhaps “makes obvious sense” (Mir & Watson, 2000, p. 946), building scientific methodology based on common sense and intuition may not be the most convincing way to proceed (Devitt, 2008).

5.1.4 Pragmatism

Recently, pragmatist philosophy has gained attention among management scholars. Similar to critical realism, it is considered to avoid the naïve ideas of easily accessible reality that positivists advocate and difficulties related to the epistemological status of findings that constructivism suffers from (Wicks & Freeman, 1998). Pragmatism accepts the researcher’s role as an active interpreter but does not agree on the search for truth as a guiding principle of science (Martela, 2015). Instead, science is considered to serve instrumental purposes. The concepts of truth and reality should be conceived by considering what practical effects they may have (Hookway, 2016). Theories are always bound to be incomplete and biased, but they may be evaluated by their practical utility: how they help serve human purposes (Wicks & Freeman, 1998). Science should hence be considered no different than other crafts that help people in dealing with their experiential worlds (Martela, 2015). As Kivinen & Piirainen (2004, p. 244) put it: “All scientific work is always done in the context of some or another research problem, and all the things considered relevant for it are considered relevant from some actor’s point.”

In contrast to critical realism, which considers alternative theories as competing against each other, pragmatists may argue that they complement each other by emphasizing different aspects and thus being useful for different purposes (Martela, 2015). This way, the under-determination argument may be resolved. This also allows for variety in methodological approaches: various forms of data and methods may be blended to create useful theories (Christ, 2013). Similarly, studies with different ontological and epistemological positions may be used, presuming that they have pragmatic value (Creswell, 2013). In their defence of pragmatism, Kivinen & Piirainen (2004) reject the idea proposed by philosophers such as Searle (2008) that scientific inquiry needs to be founded on ontological commitments. They argue that researchers

should drop ontological debates and concentrate more on methodological issues. This is, however, not the only possible conclusion. In practice, theories and their development may be inseparable from ontological and epistemological considerations and these constellations may have pragmatic value. By investigating the explicit and implicit ontological assumptions of theories and explanatory frameworks, it may be possible to develop better methodologies (Lohse, 2017).

Based on these considerations, pragmatism is adopted as the foundation of this dissertation, and provides grounds that its implications and limitations can be evaluated on.

5.2 Case study research design

The empirical studies in this dissertation all follow case study research design. Case study design is based on gathering rich data to acquire in-depth understanding of a case in its natural setting (Ridder et al., 2014). Since social phenomena are infinitely complex, researchers may arrange empirical evidence into cases to focus attention on specific aspects of them (Ragin, 2009). Case studies often combine different data sources with the goal of providing detailed descriptions of the studied phenomenon (Yin, 2009). The high level of detail is considered to be particularly suitable for answering “how” and “why” questions (Yin, 2009).

In management research, case study methodologies proposed by Eisenhardt (1989) and Yin (2009) have been widely adopted and, consequently, the goals of case research are often thought to be the identification of generalities and formulation of cause-effect propositions (Welch et al., 2011). These methodologies are often considered to have implicit positivistic assumptions (Ridder et al., 2014; Welch et al., 2011) and alternative interpretations have been proposed. The constructivist approach, proposed by Stake (2005) for example, considers the purpose of case study to increase understanding of a particular case by providing experiential knowledge of it — not generalizing the case to a population. Critical realists seek to understand the causal mechanisms beyond experiences and events, but consider the explanations to always be tentative: “By the time the research is complete, both the cases and their casing may have shifted substantially” (Ragin, 2009, p. 524). The ontological and epistemological foundations of pragmatism do not rule out any approaches to case studies in advance. Researchers should choose the combination of methods and procedures that work best for answering their research questions (Johansson, 2003), regardless of whether their logic is to generalize or particularize.

5.2.1 Theory generation, testing, and elaboration

Traditionally, case studies have been mostly associated with theory generation in the “early phases of a new management theory, when key variables and their relationships are being explored” (Gibbert et al., 2008, p. 1465). The role of case studies has been considered to formulate propositions that can then be tested

in other studies (that typically use surveys or secondary quantitative data) (Eisenhardt, 1989). This view has, however, been contested. Ketokivi & Choi (2014) argue that case studies may be used for three purposes: 1) theory generation, 2) theory testing, and 3) theory elaboration, and both qualitative and quantitative data are applicable for each of them. According to them, the defining characteristics of case research are that it is situationally grounded and seeks a sense of generality. Being situationally grounded includes paying attention to contextual idiosyncrasies and collecting data which addresses how contextual factors are related to the findings. A sense of generality does not mean making generalizations about a population but rather whether the findings provide insights to general theory in one way or another.

Theory generation aims for inductive reasoning based on empirical data without strong guidance from existing theory. In contrast, theory testing uses deductive reasoning to derive propositions from existing theory and seeks empirical support for them. In theory elaboration, researchers are interested in how a general theory appears in a specific context (Ketokivi & Choi, 2014). It may be used if a particular context is not known well enough to derive testable propositions, or if there is a desire to examine it in more detail. Elaboration may result in changes or additions to general theory by introducing new concepts, defining relationships between the concepts, or identifying boundary conditions (Ketokivi & Choi, 2014; Whetten, 1989). Theory elaboration is often thought to be based on abductive reasoning, where the tasks of collecting new empirical data and finding relevant existing theories proceed in parallel (Dubois & Gadde, 2002, 2014). In an abductive research process, empirical findings may bring about a need to redirect the existing theoretical model and similarly theoretical insights may guide data collection. Findings hence emerge through the systematic combination of theory and data.

5.3 Empirical studies

The empirical part of the dissertation comprises four studies referred to as Article 1, 2, 3, and 4, which address the topics of radical innovation and open innovation from distinct viewpoints. In Figure 4, the articles and the respective research questions of this dissertation are positioned with respect to the managerial categories needed for the development of radical innovations that were introduced in section 2.4. For the sake of clarity, the figure shows only which category an article has the strongest connection to. As can be seen from the figure, the research questions primarily address external linkages (RQs 1–3) and culture (RQ4). The articles may, however, touch on multiple categories.

Article 1 looks into three companies which leverage their users and customers as knowledge sources for digital innovation. The context of the study is the digitization of the B2B manufacturing industry, where the diffusion of new digital technologies is considered to create opportunities for radical innovation. As the article focuses on interactions with external partners, its most direct connection is to the category of external linkages. In addition, it discusses

practices related to the acquisition, distribution, and use of customer and user knowledge and therefore has links to the category of processes.

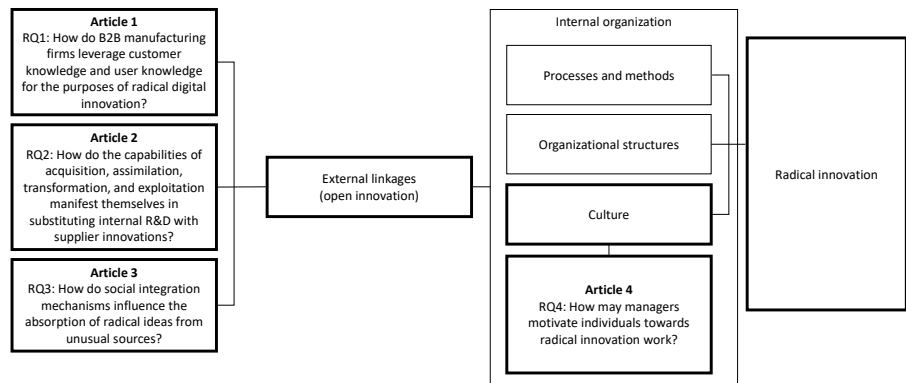


Figure 4. Categories of radical innovation management and their relations to the research questions of the dissertation.

Article 2 can be considered an embedded case study. In embedded case studies, the investigation of a single case comprises the examination of multiple of its sub-elements (Scholz & Tietje, 2002; Yin, 2009). It investigates how an energy company collaborates with its suppliers to introduce radical innovations without significant investments into internal R&D. The case is studied through four collaborative innovation projects, each case with a different supplier. The main focus is on external linkages: collaboration with suppliers. The study also touches on the topic of processes by discussing product launch strategies and describing different innovation process phases in the projects.

Article 3, similarly adopts the embedded case study design. In Article 3, the absorptive capacity of a single company is studied by looking at two of its radical innovation projects. The analysis focuses on the company's R&D unit's ability to integrate and exploit radical ideas. Furthermore, it discusses how external sources of ideas, particularly those that have no existing relations with the R&D unit, may influence the ideas' absorption. The study has a strong focus on external linkages, and it also discusses organizational structures in terms of how interactions between different parts of the organization may influence the development or radical ideas. Furthermore, it discusses decision-making mechanisms at different project phases which links it to the category of processes.

Article 4 addresses the management of individual motivation when developing radical innovations. The study develops and tests a theoretical model on individual motivation which combines the literature on innovation management and work psychology and elaborates the model by linking its elements with managerial methods. The study adopts a multi-level perspective by investigating the elements at organization, project team, and individual levels. Besides cultural issues, which are typically associated with employee motivation, the study also touches on the topics of processes and organizational structures and their links to motivation.

Table 6. Descriptions of the empirical studies.

	Article 1	Article 2	Article 3	Article 4
Research question as stated in the article	How do B2B manufacturing firms leverage customer knowledge and user knowledge for the purposes of digital innovation?	How do the capabilities of acquisition, assimilation, transformation, and exploitation manifest themselves in substituting internal R & D with supplier innovations?	How do social integration mechanisms influence the absorption of radical ideas from unusual sources?	How may managers motivate individuals towards radical innovation work?
Theoretical background	Information systems, innovation management	Absorptive capacity, innovation management	Absorptive capacity, innovation management	Work motivation, innovation management
Research approach	Theory elaboration	Theory elaboration	Theory elaboration	Theory testing, theory elaboration
Case study type	Multiple case study	Embedded case study	Embedded case study	Multiple case study
Data collection method	Semi-structured interviews, company materials	Semi-structured interviews, company materials	Semi-structured interviews, company and project materials	Semi-structured interviews
No. of companies	3	1+4	1	4
No. of projects	N/A	4	2	4
Industry	Marine products, automation and systems technologies, plant and component technologies	Energy	Steel	Technological components and systems, steel, pulp and paper, broadcasting
No. of interviews	30	18	21	57
Interviewees	R&D managers, R&D directors, product managers, design Managers, sales managers, IT managers	Project managers, supply managers, sales managers, technology managers, purchasing managers	Inventors, R&D directors, R&D managers	R&D managers, R&D developers, top managers

Whereas all of the studies adopt the case study approach, there are differences in how the individual studies were designed and conducted (Table 6). All of the studies aim for theoretical contribution by elaborating existing theories. They are guided by existing theory and seek to elaborate them by investigating relationships among concepts and examining boundary conditions (Ketokivi & Choi, 2014). The studies cannot be considered as instances of theory generation because key concepts and frameworks are adopted from previous studies. Article 4 contrasts the other studies in that a significant part of it is devoted to theory testing; propositions are generated based on extant theory and empirical support for them is assessed. It should be noted that the research question of Article 1 is slightly different to the research question 1 of this dissertation. The modification was made to focus on the study's results that are relevant for informing the management of radical innovation.

5.4 Case selection

Case studies, particularly those with theory generation or elaboration goals, typically rely on theoretical sampling, where the cases are selected based on

theoretical, not statistical, reasons (Eisenhardt, 1989). Information-rich cases are sought to provide a good fit with the questions under study (Patton, 2002). Cases may be informative for several reasons. They may be “extreme cases”, which are interesting because they are unusual or special in ways that provide valuable learning opportunities (Patton, 2002). In management research, companies which have performed extremely well, such as Toyota (Dyer & Nobeoka, 2000), have been considered valuable. In a like manner, dramatic failures can offer important lessons. An example of such a case is the investigation of Nokia’s rapid downfall from a leadership position in mobile phones (Vuori & Huy, 2016). Intensity sampling is an alternative approach which seeks informative-rich cases that are not extremely unusual but still reflect the phenomenon under study intensively (Patton, 2002). Including multiple cases in the same study provides further alternatives for sampling. The cases may be chosen to maximize variety in order to describe central themes that apply across diverse settings or to minimize variety to describe a particular setting in depth (Patton, 2002; Yin, 2009). Other sampling approaches include, for example, choosing typical cases, selecting all cases that meet predefined criteria, or purposely using random sampling (Patton, 2002). All of these strategies can be useful as long as they fit the purpose of the study.

All the empirical studies in this dissertation adopt intensity sampling as the main guiding principle in case selection. Knowledge about potential cases is gathered by reading public company documents and having discussions with company representatives. The cases are selected based on their being informative of the management of radical innovation (Article 3, Article 4), digital innovation (Article 1), and open innovation in a low R&D context (Article 2), and hence match the respective research questions. In some studies, the aim is also to focus on a particular setting in more depth. This applies to Article 1, which concentrated on B2B companies that produce complex technical products, and Article 4, where companies of relatively large size were chosen. Furthermore, Article 3 takes a step towards extreme sampling logic as it focuses on the steel industry, where the emergence of radical innovations is particularly rare. The studied projects in Article 3 are also chosen to contrast each other: one of the projects was successful and one failed and they also had different origins.

5.5 Data collection

Interviews are the primary data collection method used in all of the studies. The interviews were semi-structured (open-ended), which means that lists of themes to be explored were prepared to guide the interviews. In semi-structured interviews, detailed lists of interview questions are not always present and the interviewers are allowed to adjust their questions or add new questions based on the interviewees’ answers. The advantage of this approach is that it allows the researcher to advance to new topics based on the interviewee’s responses, which enables flexibility and openness to unexpected findings (Patton, 2002).

Intensity sampling was used for locating informative interviewees (Patton, 2002). In practice, this means locating individuals with previous experience of

the investigated topics and/or positions in the organizations that make them sufficiently knowledgeable to inform the research process. In Article 1 and Article 3, intensity sampling was complemented with snowball sampling. Snowball sampling is a sampling strategy where the initial sample is expanded by asking the interviewees to suggest new information-rich informants (Patton, 2002). The procedure may then be repeated by asking the new informants new suggestions. Snowball sampling is particularly valuable when the suitable informants are difficult to identify based on predefined criteria (Hennink et al., 2010). In addition to interview data, various documents, such as internal correspondence, process diagrams, and organizational charts (Article 3), as well as public strategy documents, annual reviews, and company presentations (Article 1; Article 2) were used to gain wider support for the findings and increase contextual understanding of the cases.

Some authors propose that data collection should be continued until theoretical saturation is reached, that is, until no new insights arise from the data (Glaser & Strauss, 2009; Hennink et al., 2010). In the studies in this dissertation, the aim was to acquire data until the research themes were explored thoroughly and in detail. The concept of theoretical saturation is, however, ambiguous and the point where a sufficient amount of data is collected is difficult to define (Bowen, 2008; Guest et al., 2006). Moreover, case studies may include moving back and forth between different research phases (Dubois & Gadde, 2002). Therefore, a sample which was initially thought to be saturated may need to be supplemented if new perspectives arise in the analysis phase. This was the case in Article 2, in which an additional interview was conducted after the initial analysis.

Several measures were taken to make the most of the interviews (Patton, 2002). The interviews were recorded and transcribed verbatim. This is beneficial, as it ensures that the interviewee's perspective is captured as fully and fairly as possible and helps overcome the limits and biases of the interviewer's attention and memory. Notes were taken during the interviews to help formulate new questions based on the interviewee's earlier responses and stimulate early insights. Immediately after an interview, the interviewers shared their observations with each other and discussed ideas and interpretations that emerged. This was also valuable for reflecting and evaluating the suitability of the interview questions used and the need for more interviews. On some occasions, the interviewees were later contacted by e-mail or telephone to clarify areas of ambiguity.

5.6 Data analysis

The data analysis phase included two distinct tasks: within-case analysis and cross-case analysis. First, the cases were analysed individually, and then cross-case patterns were identified (Eisenhardt, 1989). Within-case analyses started with thorough reading of the interview transcripts and other data for the purposes of becoming familiar with each case. In Article 2 and Article 3, which included project-level analysis, detailed project descriptions were written. Then,

the data was coded using the Atlas.ti computer program. Coding is a process where the data is selected, separated, sorted, and labelled to define what it is about (Charmaz, 2006). Computer-assisted qualitative data analysis enables the systematic use of the whole data set by forcing the researcher to be explicit in defining the codes and categories and making the links between codes and data more transparent (Kelle, 2004).

The analysis in Article 3 began with data-driven coding (Gibbs, 2008), in which events, actions, outcomes, and mechanisms were identified and labelled during the analysis. The goal was to find important elements from the case without applying a predefined framework. The reason was that, at that time, the eventual theoretical framing of the study had not been decided. Understanding of the cases was increased to direct the search for a framework (Dubois & Gadde, 2002).

Theory-driven coding was a key analysis method in all studies. It is based on a predefined set of codes that are derived from the literature and applied to the data (Gibbs, 2008). The advantage of theory-driven coding is that it provides a transparent way of moving from data to theoretical constructs (Yin, 2009). When the goal is to elaborate or test existing theory it is important to ensure that the data is actually related to the frameworks and constructs used. In all studies, transparency was further increased by presenting direct quotations from the interviews to show evidence that the findings are grounded in data. Theory-driven coding does not rule out the inclusion of inductive elements in the coding process (Gibbs, 2008). In all studies, new codes were created during the analysis to allow the emergence of new ideas and ways of categorizing the data.

Next, cross-case analysis was conducted. In cross-case analysis, similarities and differences between different cases are searched to identify patterns and boundary conditions (Eisenhardt, 1989; Yin, 2009). Comparison between cases is valuable for building explanations and testing them in systematic ways (Miles & Huberman, 1994). A common way of conducting the comparisons is to build tables in which the cases are arranged based on chosen variables (Miles & Huberman, 1994). For example, the analysis in Article 1 included building tables where the rows were determined by different types of management practices and evidence from each case was collected in separate columns. From such a table, it is easy to identify commonalities between the cases on which the findings of a study may be based. In Article 3, a similar approach allowed the identification of differences in the use of specific social integration mechanisms between the two studied projects.

Theoretical (and practical) contributions may be formulated by comparing the results of the analyses to existing theory. It is important to ensure that the findings reflect the data accurately. During the formulation of the contributions, the findings should be iteratively compared to the data (Eisenhardt, 1989; Eisenhardt & Graebner, 2007) and new data collected if needed (Dubois & Gadde, 2002). Particular attention was paid to this issue in all studies, and the data was revisited multiple times to ensure that the findings are supported by

data. Next, more details about the methodologies of the individual articles are presented.

5.7 Summary of the methodology of Article 1

In Article 1, the selection of the case companies started by defining an empirical context which would provide a fruitful setting in which to investigate the emerging practices of digital innovation. Consequently, B2B companies that produce complex technical products and are concerned with digital innovation were chosen from the heavy manufacturing industry. This setting was considered suitable because of the recent diffusion of new digital technologies in the industry (Lasi et al., 2014; Radziwon et al., 2014; Xu, 2012). Based on these criteria, three companies were chosen that are referred to as Company 1, Company 2, and Company 3 for reasons of confidentiality (see Table 7 for an overview). The companies are all multinational manufacturing companies with headquarters in Europe. Radical innovation in the context of this study refers primarily to competence-destroying innovations targeted to existing markets. Radical digital innovations were considered to have the potential to change the industry's business models, create major leaps in performance, and/or transform how the products are used. While such radical innovations had high technological novelty the companies' main concern was dealing with market uncertainty related to the demand for radical innovations by the existing customers.

To ensure the companies' interest towards digital innovation, their attitudes toward and current positions related to digital innovation were evaluated by reviewing public strategy documents, annual reviews, and public presentations by key innovation and strategy managers, and by means of discussions with firm representatives. The companies were found to differ in terms of the maturity of their digital innovation processes: Company 1 had not yet launched any large-scale digital innovation projects but was experimenting with digital technologies and building a future vision for taking advantage of the opportunities digital innovation offers. Company 2, on the other hand, had chosen digital innovation as a key strategic element, as manifested in its high level of investment in digital innovation projects of significant size and restructuring of innovation practices to support digital innovation processes. Company 3 was involved in digital innovation but was hindered by unresolved challenges related to customers' privacy concerns and access to users. Managers in Company 3 were also concerned that, because of the company's large size, it will not be sufficiently flexible to adapt to the changing needs of the market. They perceived digital innovation in the form of virtual simulation processes as crucial for their product development process, for enhancing their products' digital capabilities and for creating interfaces between manufacturers and customers with the vision of creating a digital factory.

Company 1 develops a wide range of marine systems and components related to power and propulsion, automation, and control. At the time of the study, the company was envisioning how to use digital technologies to provide new

features for ships, such as remote control, intelligent bridge control, and lower power demand. Their customers include ship companies that own and operate freight, passenger, fishing, and military ships. Users include ship captains and the technical personnel who operate the technologies. Company 2 provides automation and control systems and processing technologies for industrial customers that operate in industries like chemical, oil, pulp and paper, power generation, and mining. Typical users of Company 2 are production plant operators and power plant operators. Company 3's offering is a diverse product portfolio in the B2B sector, ranging from large-scale plants and component technologies to marine systems. The firm's customers are large organizations, and users are employees working in the customers' organizations. Typical users are operators of production plants.

Table 7. Article 1 data set.

Company pseudonym	Company 1	Company 2	Company 3
No. of interviews	9	12	9
Industry	Marine products	Automation and systems technologies	Plant and component technologies
Employees	12 000	16 000	157 000

The main data collection method was semi-structured interviews with thirty experts. The interviews with Company 3 were conducted by phone, while those for Company 1 and Company 2 were conducted face-to-face. The interview themes were based on the investigation of the potential of using customer knowledge and user knowledge in developing digital innovations. The first interview guide was open-ended so the research themes could be explored without being structured too tightly. After the first round of interviews, the interview guide was refined to deepen the discussion of emerging topics and to increase the findings' reliability (Yin, 2009). The refined interview guide is presented in Table 8. All interviews were recorded and transcribed verbatim. Multiple sources of evidence, such as public strategy documents, annual reviews, and public presentations, were used to generate more robust findings.

The first interviews were conducted with managers who had a good overview of the innovation activities in the companies. Then, employees who were involved with digital innovation in the company were identified. Selecting interviewees in advance based on their departments or job titles was an unsuitable approach for several reasons: innovation often relies on cross-functional collaboration to reach shared goals (Luca & Atuahene-Gima, 2007), and the ownership of digital innovation activities varies from company to company (e.g., between IT and R&D departments) (Ashurst et al., 2012). Furthermore, not all employees in a particular department are knowledgeable about the roles of customers and users in digital innovation. Therefore, snowball sampling was used to identify the appropriate informants (Patton, 2002). The primary contacts were asked who would be the best people to talk with about relevant topics, thereby adding new informants to our sample. Data collection was continued until additional data resulted only in minimal new information.

Table 8. Refined interview guide used in Article 1.

Interview theme	Questions
Details about the interviewee	<ul style="list-style-type: none"> • What is your position and area of responsibility? • What is the product your business unit is offering? • How long have you worked in this position? How have you worked in the company? • What is your educational background? • Who do you work with within the company? • Do you have direct user/customer contact? • Which stages of the innovation process does your area of responsibility cover? Can you shortly describe the process?
Users and customers	<ul style="list-style-type: none"> • Who are the users of the product? • Who are the customers of the product? • What kind information/knowledge do you need from users/customers in your innovation processes? <ul style="list-style-type: none"> ◦ How is it currently made available? Is there a link to operations? • How do you utilise the user/customer knowledge from operations of a previous project in the innovation process? / What do you do with the information you got from users/customers? <ul style="list-style-type: none"> ◦ What format does the user/customer knowledge need to have to be useful for you to apply it in the innovation process? ◦ When would you need user/customer knowledge? Are there specific times in the innovation process when you would need the information? ◦ Do the information requirements change throughout the projects? • What kind of tools and/or structured ways are used to access user/customer knowledge? (e.g. a database) • Where and how is user/customer knowledge stored or documented? • How is user/customer information is distributed in the organisation? • What attributes would a user/customer knowledge system need to have to include user/customer knowledge in the innovation process?
Digitization	<ul style="list-style-type: none"> • How do you understand digitization in the manufacturing industries? • How does increasing digitization in the manufacturing industries change your firm's way of doing business? <ul style="list-style-type: none"> ◦ Does digitization create new opportunities for innovation? <ul style="list-style-type: none"> ▪ What kind of innovation? Incremental vs radical? ◦ Does digitization pose threats to your business? <ul style="list-style-type: none"> ▪ What kind of strategies can be used to overcome the threats? • How does digitization help or promote innovation activities? • How digitization will/has change(d) your innovation processes? • How does digitization affect your own work? • How does digitization change the role of users/customers in the innovation process? • Does utilisation of user/customers knowledge in increasing digitization lead towards new opportunities? <ul style="list-style-type: none"> ◦ If yes, how?

In Company 1, most of the informants were design managers and design specialists who performed development work but were not in contact with customers or users themselves. Their responsibilities, that is, to renew their product offerings to meet market demand, were similar to those of R&D managers in the other companies. In Company 2, most of the data was collected from two R&D teams. The first team focused on hardware, while the second team focused on software. The interviewees, who had titles like R&D manager and R&D director, were suggested based on their wide view of the firm's digital innovation activities. Employees in R&D who were knowledgeable about customer knowledge or user knowledge were also interviewed based on suggestions. The first couple of interviews revealed that the firm was in the process of implementing a new company-level strategy in which digital innovation is a significant element. This information led to interviews with two top managers who were closely involved in formulating the new strategy. Whereas digital innovation was primarily the R&D/design teams' responsibility in Company 1 and Company 2, the IT department had a bigger role in Company 3. The primary contact person, a senior IT manager who served as the entry

point into the organization, suggested suitable employees who were concerned with digital innovation in the organization, which covered the developed products from the IT and R&D perspectives.

Following a replication logic (Eisenhardt & Graebner, 2007; Yin, 2009), qualitative data analysis programs and a coding scheme deduced from the interview guide were used to analyse each case individually. The research team members discussed the findings of each case, and emergent topics led to an iteration of the coding scheme. With this updated coding scheme, the cases were analysed again. The coded data formed the base for cross-case analyses, during which the data was revisited in an iterative process and emerging findings collected into tables. Thus, the analysis process focused on matching patterns across the cases and building explanations for what occurred in the data.

5.8 Summary of the methodology of Article 2

For the purposes of the study, a company which introduces innovative products and services and relies on its suppliers instead of internal R&D in doing so was sought in Article 2. Fortum, a multinational energy utility company was selected on the basis that it is innovative, has low R&D intensity, and puts a high priority on collaborating with suppliers for innovation. Fortum can be described as a scale intensive company (Trott, 2005), whose assets mainly consist of process technology and whose internal capabilities involve design, engineering, and operations, rather than intensive R&D. New products and services typically emerge through the commercialisation of technologies developed by suppliers. The competitive advantage of a scale intensive company is derived from lower operating costs compared to competitors. According to the OECD definition (IPTS, 2015), Fortum qualifies as a low R&D intensive company on the basis of having R&D expenditures of less than 1% of sales (0.9% in 2014). In general, high R&D intensive companies may invest well over 10% of their sales in R&D. The R&D intensity of Google, for example, was as high as 14.9% in 2014 (IPTS, 2015).

Fortum produces and markets energy and heat for consumers and business customers, the main market being in the Nordic countries. Its production portfolio utilises several energy sources, hydropower, nuclear power, and it runs combined heat and power plants. Fortum aims at improving its competitiveness in climate issues and reductions in CO₂ emissions. The company's strategy is to strengthen and streamline its core businesses, but at the same time it has a strong need to find new business areas based on various emerging technologies and energy sources, pressured by environmental legislation and international agreements. The company actively searches for ways to build new environmentally-benign power generation based on renewable energy sources: solar, wind, and wave power.

Fortum has chosen to maintain internal technology development in one of the core business segments but new business development relies solely on suppliers' technological solutions. The corporate R&D unit focuses on designing

and piloting new product types and business models instead of developing new technologies. Fortum considers open innovation as a means to introduce innovations at a rapid pace without major investments into internal R&D.

Table 9. Case selection in Article 2.

	Technological novelty	Strategic importance	Supplier involvement
	<i>The case should concern an innovation project with technological innovation with commercial targets.</i>	<i>The case should be of strategic importance to Fortum.</i>	<i>The case should involve a supplier with a significant innovator role.</i>
Case Heat	New technology that reduces customers' energy costs.	New business area connected to the energy consumption of households.	Supplier Bravo was the sole technology provider and has patented the solution.
Case Solar	New technology that lowers the threshold to apply solar power.	New business area, connected to utilising solar energy in households.	Supplier Charlie developed the actual technological solution, the original idea and need for it came from Fortum.
Case Bio	New technology that refines a side stream of a raw material into a saleable product.	Core business area, connected to power plant efficiency.	Supplier Delta developed the refining process.
Case Carbon	New technology that saves the environment and lowers EU emission trading costs.	Core business area, connected to power plant emissions.	Supplier Echo developed a process to cut the emissions.

The selection of the cases was initiated through discussions with the Vice President of Procurement, Chief Technology Officer, and other personnel related to innovation and supply management. First, an initial list of 50 major collaborative innovation projects with suppliers during the years 2009–2015 was gathered from public sources, such as company stock exchange releases. The projects were then reviewed with the company representatives and shortlisted based on three criteria: *technological novelty*, *strategic importance*, and *supplier involvement* (Table 9), to fit the topic of substituting internal R&D with supplier innovation. Four case projects were selected, two of which aimed at the renewal of the company's core businesses (Cases Bio and Carbon) with radical technological competence-enhancing innovations and two (Cases Heat and Solar), which aimed at the introduction of new business areas with Fortum and provide their existing customers novel products with potentially disruptive effects on the energy markets (McDowall, 2017). In all cases new technology developed by a supplier, was applied. Two of the cases (Case Heat and Case Solar) address the development of new-to-the-market products and two of them (Case Bio and Case Carbon) new-to-the-world products. They all therefore fulfil the definition of radical innovation as defined in this dissertation.

Multiple data collection methods were combined. Informal meetings, presentations, and company reports were used to ground the research. Interviewing was the main data collection method; the main data consists of qualitative data from 18 interviews (Table 10). Informants were selected using a purposive sampling technique — i.e. identifying key people related to the innovation projects. Typically, these people were located in the case company's R&D and procurement units. Furthermore, the informants were asked to identify subsequent informants from the supplier companies, who were also interviewed. This was considered important since the literature on open

innovation with suppliers is dominated by studies which consider only the buyer's perspective (Chung & Kim, 2003) and one-sided investigations may result in limited or biased understanding about the impact of the buyer's actions. The positions of the interviewees vary from case to case due to different compositions of the project teams of a) Fortum and b) of the suppliers, and c) varying levels of access to the suppliers.

Table 10. Article 2 data set.

Company name	Fortum
No. of interviews	Case Heat interviews: 3 Case Solar interviews: 4 Case Bio interviews: 3 Case Carbon interviews: 3 General interviews: 5 Total interviews: 18
Industry	Energy
Employees	8 000

The interviews were semi-structured and four researchers participated in data collection. Data collection instruments included the following sections: interviewee information, case background, and semi-structured questions about the collaborative innovation project. The interview guide covered questions about the novelty of the innovation and its significance to Fortum's strategy, the capabilities of each party, and how each phase of the projects was managed (Table 11).

Table 11. Interview guide in Article 2.

Interview theme	Questions
Interviewee profile	<ul style="list-style-type: none"> Name, title, and organisation Position in the organisation during the case project Work history
Case profile	<ul style="list-style-type: none"> Describe the innovation project. What business area and supply management category does this project belong to? Who is the primary customer for this innovation? Who was (were) the primary supplier(s) for this innovation? What was the origin of the innovation idea (e.g. internal party, existing supplier, new supplier) Describe the novelty of this innovation How did this innovation effort relate to the company's technology strategy? Who at your organisation and your supplier's organisation were involved in establishing the business relationship? How was the process of supply market intelligence conducted? What tools/processes were used with suppliers in creating and evaluating the business case? What kind of formal contracts were in place before a formal investment decision? When and how was final investment decision made? Who at your organisation and your supplier's organisation were involved in the project? What did each party bring to the project? What was the contractual model used for this project? How was IPR managed, and what was the role of IPR in the case? How the supplier relationship was managed? How did the level of technical competence in your company affect the collaboration? How systematic was the collaboration between the project and the supply management employees? How useful was supply management knowledge regarding the innovation case? How much did the collaboration with a supplier affect the outcome of the project? How did your company culture affect the collaboration? How would you evaluate the success of the project? What could have been improved in this collaboration?

The same questionnaire in a modified form was used when interviewing the supplier companies.

The data analysis proceeded in three phases. First, a within-case analysis was conducted based on the interview data and supplementary material. The cases were processed into the form of detailed case study write-ups. The aim was to understand different phase of the innovation processes, what the innovations were about, how they were managed, and what each party's role was.

After the initial analysis, the attention was shifted back to the literature and theory which would explain our emerging findings was looked for. Consequently, the absorptive capacity process framework was adopted (Zahra & George, 2002). The view of what our cases are, therefore, evolved throughout the process as understanding of the empirical context and its compatibility with theoretical concepts increased (Dubois & Araujo, 2007; Dubois & Salmi, 2016). At this point, an additional interview was conducted to find answers to questions that had arisen during the process. This interview focused particularly on Fortum's capabilities and how they might be utilised differently in cases when internal R&D is substituted with supplier innovations compared to areas where Fortum has strong internal R&D. The case descriptions were then revisited and the initial findings were matched to the four capabilities related to the absorptive capacity process. Existing operationalisations were relied on to link the interview data and themes which emerged from the interviews with corresponding capabilities (Table 12). In this manner, the analysis process moved back and forth between theory and data and thus resembled the abductive process of inquiry (Dubois & Gadde, 2002, 2014).

Table 12. Indicators of absorptive capacity capabilities and related interview themes.

Indicators proposed in the literature	Interview themes
Acquisition	
<ul style="list-style-type: none"> • Ability to detect opportunities in the environment (Noblet et al., 2011). • Openness towards the environment (Camisón & Forés, 2010) • Proactive discovery of new opportunities to be exploited (Forés & Camisón, 2016) 	<ul style="list-style-type: none"> • Supply market intelligence. • Technology scanning. • Identifying and evaluating external technologies.
Assimilation	
<ul style="list-style-type: none"> • Ability to use employees' knowledge, experience and competency in the assimilation and interpretation of new knowledge (Forés & Camisón, 2016) • Integration of external knowledge (Noblet et al., 2011) • Individuals that are highly capable at understanding external technologies (Nemanich et al., 2010) 	<ul style="list-style-type: none"> • Internal technical competences. • Sharing of technological knowledge. • In-depth learning about new technologies.
Transformation	
<ul style="list-style-type: none"> • Firm's capability to adapt technologies designed by others to its particular needs (Forés & Camisón, 2016) • Ability to understand the consequences of changing market demands in terms of new products and services (Jansen et al., 2005; Leal-Rodríguez et al., 2014) • Ability to challenge established thinking or practices (Noblet et al., 2011) 	<ul style="list-style-type: none"> • Formulating a business model. • Agreeing on a commercial vision. • IPR ownership. • Contract negotiations.
Exploitation	
<ul style="list-style-type: none"> • Application of external knowledge (Noblet et al., 2011) • Achievement of organisational goals (Noblet et al., 2011) • The project has clear division of roles and responsibilities (Popaitoon & Siengthai, 2014) 	<ul style="list-style-type: none"> • Product introductions. • Project success. • Operational roles and responsibilities.

In the third phase, the findings were compared across cases. The focus was on the four capabilities derived from the framework, and technique of pattern coding was used to enable cross-case comparisons (Miles et al., 2013). The coding was based on spreadsheets, tables, and graphical presentations, where the cases were compared according to the selected categories to create in-depth understanding of each case and their similarities and differences. Four researchers participated in the coding and analyses of the cases. The analyses were a highly interactive collaborative effort among multiple researchers with frequent discussions to reach consensus in coding and in drawing conclusions.

5.9 Summary of the methodology of Article 3

Article 3 investigates Steel Inc., which has a steady market position, a successful track record in introducing incremental innovations, and some experience in developing radical ideas into innovative products and processes. It was selected for the study for several reasons. First, it is an incumbent company interested in developing radical innovations, which allows investigation of tensions between core capabilities and renewal (Leonard-Barton, 1992). Second, it provided access to two radical innovation projects originating from unusual idea sources enabling the investigation of a novel context. The ideas can be considered as competence-enhancing technological inventions. They were also associated with high market uncertainties related both to existing markets and new market segments. Third, the case comprises one successful and one failed project which diminishes survivorship bias that could arise from focusing only on success stories. Fourth, the industry context is considered to be very challenging for the development of radical innovations. Studying such extreme circumstances is likely to provide novel insights (Yin, 2003).

Table 13. Article 3 data set.

Company pseudonym	Steel Inc.
No. of interviews	Project 1 interviews: 7 Project 2 interviews: 6 General interviews: 8 Total interviews: 21
Industry	Steel
Employees	7 000

The main data collection method was semi-structured interviews with involved employees and the inventors (Table 13). In selecting the interviewees, the first step was to ask a senior R&D Director to identify relevant employees. To ensure that all relevant informants were found, snowball sampling was also used (Patton, 2002). After the end of each interview, the interviewees were asked who else is knowledgeable about the development of the ideas, thereby adding new informants to the sample (Lewis-Beck et al., 2004). The interview guide (Table 14) covered the treatment of ideas from external sources, details of the projects, and general questions about the innovation management system in use. It should be noted that the word “project” is here used in a broad sense including events that occurred both before and after official project statuses were granted for the development of the ideas. This covers informal and formal activities from

the fuzzy front-end (Koen et al., 2005) to new product development and commercialization.

Total of 21 interviews, lasting typically between 1 and 2 hours, were conducted, recorded, and transcribed verbatim. At least two researchers participated in all interviews. The company also provided access to additional data (total amount of ~100 sheets) which included internal memos and e-mail correspondence which increased understanding about the projects, as well as process diagrams and organizational charts which illustrated the innovation management system in use.

The projects were first analysed individually as suggested by Yin (2009). Descriptions of them were written to create coherent representations of the chains of events. Both the interview transcripts and relevant documents were coded. At first, the data was coded inductively in a data-driven fashion (Namey et al., 2008). An important guiding principle at this stage was to identify events, actions, and their outcomes in the idea journeys and the interviewees' explanations of their driving forces and inhibitors.

Table 14. Interview guide used in Article 3.

Interview theme	Questions
Details about the interviewee	<ul style="list-style-type: none"> • How long have you worked at Steel Inc.? • What is your role in the company?
Ideas from external sources	<ul style="list-style-type: none"> • How often do you receive ideas from outside the R&D unit? • What are the ideas typically like? • How do the ideas find their ways to the unit? • How are the ideas treated? • How are they evaluated? • Which factors affect whether the ideas are further developed? • What are the strengths and weaknesses of the current methods? • Can you give concrete examples related to such ideas? • In what ways are external ideas treated differently from internal ideas? • Why are they treated differently? • What is the general attitude towards external ideas? Why?
Project-specific questions	<ul style="list-style-type: none"> • What was the origin of the idea? • When did you become aware of the idea? • What was your first impression of the idea? • What has been your role in the project? • What has happened to the idea in the organization? • What has been done right? Is there room for improvement somewhere? • How has the idea been evaluated? • How would you evaluate the idea's fit with the company's portfolio? • Who has made decisions about the idea? • Who have you discussed about the idea? • Was the idea representative of external ideas that you receive? • Was there motivation to develop the idea in the organization? • What was the status of the project compared to other innovation projects? • How novel was the idea? How high was its potential? • How did the novelty influence its reception? • What kind of risks were associated with the idea? • Were potential applications for the idea searched for? By whom? If not, why? • How did the origin of the idea influence its reception?
Innovation management system	<p>Open-ended questions on aspects of the company's innovation management system:</p> <ul style="list-style-type: none"> • Organizational structures • Cross-functional collaboration • External relationships • Innovation strategy • Innovation processes • Organizational culture • Measurement • Management practices • Human resources

Selective coding (Strauss, 1987) was used to understand the data in light of the existing frameworks of absorptive capacity capabilities and social integration mechanisms. The analysis proceeded by matching different events in the projects with the four absorptive capacity capabilities and assessing the levels of the absorptive capacity capabilities. This phase was strongly guided by extant literature. Studies on absorptive capacity capabilities were investigated to generate a list of indicators which suggest high capability levels. These indicators helped operationalize the capabilities and identify elements in the projects that could be used to evaluate capability levels in the context of this study. Table 15 shows how literature on absorptive capacity capabilities was used to interpret the interview data. To understand how different absorptive capacity capabilities performed in the projects their levels were assessed by looking for comments which indicated high or low success in key elements associated with each capability. If multiple informants argued that, for example, the managers were not initially interested in the proposed ideas (Cegarra-Navarro & Sánchez-Polo, 2008; Cepeda-Carrion et al., 2012; Forés & Camisón, 2016; Hurley & Hult, 1998) this was considered to support the evaluation of low acquisition capability in the project. If there were both positive and negative assessments of a capability in the context of a specific project without a clear majority towards either direction, the capability level was considered to be medium.

Table 15. Examples of identified social integration mechanisms with illustrative quotations.

Social integration mechanism	Category	Illustrative quotations
Shared language, background, and education	Socialisation mechanisms	<p>"Those who tinker around in their garage are better equipped to interact with this kind of person than those who have spent their career in a laboratory looking through a microscope."</p> <p>"They have been interested but I don't always know how to validate my idea. Many times there's a language barrier, they speak a different language than us. I haven't had a formal education of any kind so I have a different way of expression."</p>
Practices for knowledge transfer	Coordination mechanisms	<p>"It's amazing how well our coffee room discussions advance the development projects. There's several ongoing discussions all the time, and that's how the knowledge is transmitted. Of course some of the knowledge is irrelevant but some of it is extremely valuable."</p> <p>"We have an ongoing informal meeting procedure, like a brainstorming session for current topics. When people have ideas, thoughts, problems, or technical stuff there's the whole group advising and supporting them."</p>
Boundary spanners	Coordination mechanisms	<p>"The kind of person who can really set things in motion in the organization. By being at halfway between us and the management he has a position with good opportunities to influence others. He uses slogans and simplifies and exaggerates things a bit so that everybody understands him."</p> <p>"He is capable of winning people over and getting things done. It's important to know your way around the informal organization hierarchies and know who might be sympathetic for the idea and should be invited to meetings."</p>
Formalisation	Systems mechanisms	<p>"The strict non-disclosure agreement is a problem for our organization since we can't discuss almost anything with our colleagues. Usually we talk and speculate about the projects openly. It promotes them and generates theories and shared understanding. If we have to be silent, that doesn't happen."</p> <p>"Non-disclosure agreements don't fit to our culture. If we aren't allowed to discuss ideas, a major innovation factor is wasted. Also, it doesn't motivate since for me and many others it is very inspiring to discuss with colleagues and pour out problems to them."</p>

Table 16. Indicators, key project elements, and illustrative quotations of absorptive capacity capabilities

Indicators proposed in the literature	Key elements in the case projects	Illustrative quotations and related capability assessments
Acquisition		
<ul style="list-style-type: none"> • Ability identify and quickly acquire knowledge (Ritala & Hurmelinna-Laukkanen, 2013; Roberts, 2015) • Ability to detect opportunities in the environment (Noblet et al., 2011) • Effective routines to identify, value, and import new knowledge (Roberts, 2015) • Effort to increase the number of our information sources (Ritala & Hurmelinna-Laukkanen, 2013) • Innovation is readily accepted in programme/project management (Cepeda-Carrion et al., 2012; Hurley & Hult, 1998) • Management that actively seeks innovative ideas (Cepeda-Carrion et al., 2012; Hurley & Hult, 1998) • Management that has tried to initiate projects and introduce innovations (Cegarra-Navarro & Sánchez-Polo, 2008; Cepeda-Carrion et al., 2012) • Managers that are open to new ideas and new ways of doing things (Cegarra-Navarro & Sánchez-Polo, 2008; Cepeda-Carrion et al., 2012) • Openness towards the environment (Camisón & Forés, 2010) • Proactive discovery of new opportunities to be exploited (Forés & Camisón, 2016) 	<ul style="list-style-type: none"> • Gaining access to radical ideas from different sources. • Managerial interest in radical ideas at different hierarchical levels. • Recognizing the initial value of radical ideas. 	<p>"I proposed my idea to the managers but was outright rejected with references to metallurgy theory and the latest advances in the industry. It became clear to me that I was wrong and the idea was unfeasible." (indicates low acquisition capability)</p> <p>"Our CEO received a letter from the inventor and took the idea seriously from the very beginning. He then sent a couple of specialists to visit him and discuss potential collaboration." (indicates high acquisition capability)</p>
Assimilation		
<ul style="list-style-type: none"> • Ability to quickly understand new opportunities to serve clients (Jansen et al., 2005) • Ability to use employees' knowledge, experience and competency in the assimilation and interpretation of new knowledge (Forés & Camisón, 2016) • Assimilation of the external knowledge and its intrinsic value (Noblet et al., 2011) • Capability to assimilate new technologies and innovations that are useful or have proven potential (Forés & Camisón, 2016) • Human resources (Camisón & Forés, 2010) • Involvement in spreading knowledge (Camisón & Forés, 2010) • Managers that recognize the value of new information, assimilate it and apply it (Cegarra-Navarro & Sánchez-Polo, 2008; Cepeda-Carrion et al., 2012) 	<ul style="list-style-type: none"> • Investigating technological and commercial aspects of the idea. • Conducting manufacturing tests. • Leveraging relevant knowledge, experience and competency in understanding the idea. 	<p>"We had to conduct the first manufacturing test in secret because we couldn't get a permission for it. Others explicitly opposed the idea: if it was possible someone else would have invented it already." (indicates low assimilation capability)</p> <p>"We examined the material samples to see if some special properties emerge through heat treatment. The thing is, however, that these metallurgical studies rarely reveal anything that we don't already know from the literature. We could of course outsource manufacturing tests to our partners with suitable equipment but that approach is not very attractive as it requires more resources and is risky." (indicates low assimilation capability)</p>

Transformation		
<ul style="list-style-type: none"> • Ability to challenge established thinking or practices (Noblet et al., 2011) • Ability to quickly recognize the usefulness of new external knowledge to existing knowledge (Jansen et al., 2005; Leal-Rodríguez et al., 2014; Popaitoon & Siengthai, 2014) • Ability to understand the consequences of changing market demands in terms of new products and services (Jansen et al., 2005; Leal-Rodríguez et al., 2014) • Awareness of the firm's competencies in innovation, and the capability to eliminate obsolete internal knowledge which stimulates the search for alternative innovations (Forés & Camisón, 2016; Noblet et al., 2011) • Capability to co-ordinate and integrate all phases of the R&D process and its inter-relationships with the functional tasks of engineering, production and marketing (Forés & Camisón, 2016) • Firm's capability to adapt technologies designed by others to its particular needs (Forés & Camisón, 2016) • Informal conversations in the organization that involve commercial activity (Jiménez-Barrionuevo et al., 2011) • Periodical meetings to discuss the consequences of market trends and NDP (Jansen et al., 2005; Leal-Rodríguez et al., 2014; Popaitoon & Siengthai, 2014) • Renewal capability (Camisón & Forés, 2010) 	<ul style="list-style-type: none"> • Rethinking the company's scope. • Finding new application areas. 	<p>"Since it's such a novel thing it competes with other projects which have more data available to support them, are closer to our own process, and can be implemented with our current equipment or with just small changes." (indicates low transformation capability)</p> <p>"After we acquired hard proof from the first manufacturing tests, things started slowly progressing, but even then we struggled to do more tests. When we found some customers and more people started to be convinced of what we were doing we still had to fight to get money for the needed investments. To put it bluntly, we wasted a lot of time by arguing with each other." (indicates low transformation capability)</p>
Exploitation		
<ul style="list-style-type: none"> • Achievement of organizational goals (Noblet et al., 2011) • Application of the assimilated external knowledge (Noblet et al., 2011) • Capability to put technological knowledge into product and process patents (Camisón & Forés, 2010; Forés & Camisón, 2016) • Capability to use and exploit new knowledge in the workplace to respond quickly to environment changes (Forés & Camisón, 2016) • Constant considerations how to better exploit knowledge and technologies (Jansen et al., 2005) • Degree of application of knowledge and experience acquired in the technological and business fields to the firm's strategy that enables it to stay at the technological leading edge in the business (Forés & Camisón, 2016) • New knowledge exploitation (Camisón & Forés, 2010) 	<ul style="list-style-type: none"> • Introducing new products. • New market creation • Initiating operations. 	<p>"At first, we delivered improved products to our existing customers, but then we realised that we can also make other kinds of products with the new process. We started to systematically look for markets for a new type of steel. This required close collaboration with sales, marketing, and technical support teams. There was not much domestic demand so we put effort to market the new products globally." (indicates high exploitation capability)</p> <p>"From the point of view of our strategy, this isn't a great fit. And we don't feel it's in our best interest to be involved in scaling up the production." (indicates low exploitation capability)</p>

As in Article 2, extant studies on absorptive capacity guided the analysis by providing lists of relevant social integration mechanisms which could be used to identify and categorize similar mechanisms from the projects (see Table 16). Typically, mentions of social integration mechanisms appeared in relation to key capability elements which made possible to link social integration mechanisms and absorptive capacity capabilities together. The codes and categorisations were constantly compared to the data to ensure their consistency. Finally, the projects were compared with each other by arranging them into tables and matching the identified patterns. Key informants were met several times to discuss the emerging findings and confirm their validity. Comparability of the findings from the projects is supported by the inclusion of the general interviews and documents, which enabled triangulation among different data at the project and organizational levels (Miles & Huberman, 1994).

5.10 Summary of the methodology of Article 4

In Article 1, the companies were selected based on their involvement in radical innovation. The companies needed to have radical innovation activities and an interest in pursuing radical innovation. Furthermore, they were required to have ongoing radical innovation projects. Fulfilment of this criterion was evaluated in each organization, based on conversations with a senior R&D manager with a good overview of the organization's innovative activities. All organizations were incumbent companies with between 3 000 and 20 000 employees. The companies were chosen from different industries and with different emphasis and experience in developing radical innovations to identify contrasting patterns in data within the general context (Table 17). The scope of the study is broad in that it includes different types of radical innovations: both competence-enhancing and competence-destroying innovations, radical technical innovations, and radical innovations that target new markets.

Interviewees were located with the help of a senior R&D manager in each company. They were asked to suggest managers and employees who have experience of radical innovation development in the organization. In addition, a recent radical innovation project was identified in each company and several employees working with the project were interviewed. These two samples were allowed to overlap, and the criteria resulted in 7–19 interviewees from each company. The interviews lasted typically between 1 and 1.5 hours.

Table 17. Article 4 data set.

Company pseudonym	Process Inc.	Steel Inc.	Forestry Inc.	Broadcasting Inc.
No. of interviews	13	19	7	18
Industry	Technological components and systems	Steel	Pulp and paper	Broadcasting
Employees	16 000	7 000	20 000	3 000
Primary innovation goal	Cost cutting and efficiency focus	Exploiting previous breakthroughs	Burning platform – redirecting business	Increasing focus on radical innovation

No detailed interview guide was relied on in the interviews as the goal was to gain understanding of the interviewees' own experiences of the development of radical innovation. The role of the interviewers was to ask open-ended questions to access the interviewee's perspective (Qu & Dumay, 2011). General themes related to the management of radical innovations, such as processes, organizational structures, knowledge transfer, and rewarding were often used to guide the conversation and some questions related to them were listed beforehand to support the interviews. The interviewers were allowed to react to topics that the interviewees brought up. The aim was to indirectly acquire knowledge about their attitudes towards and evaluations of radical innovation and associated tasks, how radical innovation is managed in the organization, and how they perceive related managerial actions. Also, the company strategy was discussed to acquire an understanding of the role of radical innovation in each organization. Interviewees associated with the projects were asked to describe the development process of the project, its challenges and successes, how the work environment and managerial actions influenced the project, and how the project compares to other radical and incremental innovation projects in the organization. Investigating a recent project has the benefit of acquiring understanding about the respondents' experiences of concrete events from cognitive, affective, and behavioural viewpoints (Gremier, 2004).

Article 4 has a strong emphasis on theory-testing and a central part of the analysis was to compare the collected data with propositions derived from the literature⁶. The analysis started with a within-case analysis (Eisenhardt, 1989), in which the interview transcripts were read multiple times to become familiar with each organization. Details of the management systems of the organizations and the employees' perceptions were written down. After this, relevant passages of the data were coded. A passage is here defined as the entire segment of speech until the interviewer asks the next question. Coding was based on the propositions formulated based on extant literature. Table 18 reports how the codes were distributed among the companies and the propositions (P1–P11). The analysis then proceeded by the means of qualitative pattern matching between theory and data (Yin, 2003). Support for the propositions was evaluated by examining the coded transcripts and seeking instances where the interviewees explicitly or implicitly supported the propositions.

Table 18. Frequencies of codes per company (shares of total number of codes).

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	Total
Steel Inc.	4 (3%)	4 (3%)	8 (5%)	11 (8%)	4 (3%)	20 (14%)	7 (5%)	22 (15%)	46 (32%)	12 (8%)	8 (5%)	146 (100%)
Forestry Inc.	5 (4%)	30 (24%)	15 (12%)	5 (4%)	12 (9%)	14 (11%)	21 (17%)	4 (3%)	7 (6%)	10 (8%)	4 (3%)	127 (100%)
Process Inc.	2 (2%)	11 (10%)	13 (12%)	12 (11%)	10 (10%)	7 (7%)	4 (4%)	15 (14%)	21 (20%)	5 (5%)	5 (5%)	105 (100%)
Broadcasting Inc.	26 (16%)	15 (9%)	19 (12%)	16 (10%)	13 (8%)	8 (5%)	19 (12%)	3 (2%)	13 (8%)	31 (19%)	0 (0%)	163 (100%)
Total	37 (7%)	60 (11%)	55 (10%)	44 (8%)	39 (7%)	49 (9%)	51 (9%)	44 (8%)	87 (16%)	58 (11%)	17 (3%)	541 (100%)

⁶ A list of the propositions can be found in section 6.4 where the findings of the study are discussed.

The article also included a theory elaborating part, where the propositions were elaborated by reporting of managerial methods that the informants associated with the propositions. The identification of such concrete methods enriches the model by 1) increasing its practical relevance and 2) allowing the establishment of further linkages to existing management theory.

5.11 Validity and reliability

The soundness of qualitative research can be judged on certain criteria and methods to fulfil them. As an example, many authors emphasize the value of triangulation, where researchers search for convergence among multiple different data sources, use multiple methods, and include multiple researchers (Creswell & Miller, 2000). These methods have, however, different purposes depending on the philosophical position adopted. Whereas Eisenhardt (1989) and Yin (2009) argue that these methods are used to increase the objectivity of the findings, Stake (2005), as a constructivist, argues that they are needed to make the cases more understandable to others. Critical realists may argue that these methods are helpful in reaching a tentative epistemological closure (Easton, 2010).

Table 19. Methods to ensure research quality.

Criterion	Method	Applies to Article #
Objectivity/ Confirmability	Description of the data collection and analysis processes	1, 2, 3, 4
	Using multiple data sources	1, 2, 3
	Using multiple interviewers	1, 2, 3, 4
Reliability/ Dependability/ Auditability	Database with all available documents, interview transcripts, archival data, etc.	1, 2, 3, 4
	The studied organization's name is mentioned explicitly	2
	Matching patterns across cases	1, 2, 3, 4
Internal Validity/ Credibility/ Authenticity	Using multiple data sources	1, 2, 3
	Recording and transcribing interviews	1, 2, 3, 4
	Using multiple interviewers	1, 2, 3, 4
	Confirming the findings by the informants	2, 3
	Research framework explicitly derived from the extant literature	1, 2, 3, 4
External Validity/ Transferability/ Fittingness	The underlying logic of case selection is explained	1, 2, 3, 4
	The case study contexts are described	1, 2, 3, 4
	The findings are connected to prior theory	1, 2, 3, 4
	Limitations on the transferability of the findings are discussed	1, 2, 3, 4
	Multiple cases	1, 2, 3, 4
Utilization/ Application/Action Orientation	Practical implications are addressed in the articles	1, 2, 3, 4
	Interim or final results are presented to the members of the studied organizations	1, 2, 3, 4

In practice, the suggestions for conducting high-quality research are not too far from each other, regardless of the philosophical positions. For example, a positivist may be concerned with a study's external validity, that is, to which domain its findings can be generalized (Patton, 2002; Yin, 2009). A constructivist would likely deny the idea that the findings could be generalized to a larger population, but put effort in ensuring their transferability (Lincoln & Guba, 1985). Transferability would allow other researchers to make judgements about whether the findings are valuable in their context without making claims about which contexts they are applicable to. Nevertheless, both the positivist and the constructivist would likely try to produce a detailed description of the

case study context in more or less similar ways (Gibbert et al., 2008; Lincoln & Guba, 1985)

In line with the pragmatist approach adopted in this dissertation, no definite interpretations or criteria are derived from ontological and epistemological assumptions. However, the practical value of such criteria is acknowledged and the status of particular methods for ensuring research quality is considered to arise from their benefits in helping researchers create more useful theories (Wicks & Freeman, 1998). As a solution, a combination of positivist and constructivist perspectives on research quality, as proposed by Miles et al. (2014), is adopted. The research process is evaluated based on five broad criteria:

- Objectivity/Confirmability: relative neutrality and reasonable freedom from unacknowledged researcher biases
- Reliability/Dependability/Auditability: whether the research process is consistent and reasonably stable over time and across researchers and methods
- Internal Validity/Credibility/Authenticity: whether the findings make sense and are credible to the research subjects and readers
- External Validity/Transferability/Fittingness: whether the findings are transferable or generalizable to other contexts
- Utilization/Application/Action Orientation: the impact of the study on researchers, research subjects, and readers

Table 19 describes how these criteria were addressed in the individual studies.

This section has introduced the philosophical and methodological positions of this dissertation and described the empirical studies that have been conducted. In the next section, the main findings of the dissertation are presented.

6. Findings

The findings chapter is divided into four parts to answer the four research questions presented in the dissertation. Four studies have been conducted which each answer to one of the research questions. First to be presented are the findings that address the leveraging of customers and users for the purposes of radical digital innovation in the B2B manufacturing industry. The second part presents findings related to the substitution of internal R&D with supplier innovations. Next, the third part focuses on the absorption of radical ideas from unusual sources. Finally, the fourth part addresses individual motivation towards radical innovation work.

6.1 Article 1: “The role of users and customers in digital innovation: Insights from B2B manufacturing firms”

Article 1 studies a setting where new digital technologies, such as sensor technologies, radiofrequency identification tags, big data, cloud computing, and Internet of Things are increasingly adopted in B2B companies, such as power plant and ship manufacturers, that manufacture complex technical products. This creates a fluid phase of experimentation where the opportunities to revolutionize the existing product designs and business models increase significantly (Nylén & Holmström, 2015; Yoo et al., 2012). Products in the studied industry are typically very costly and have long product life-cycles, spanning even multiple decades (Griffin & Belliveau, 1997). Because of this, innovation has mostly focused on improving performance and reliability of the products and major changes in product and service designs have been rare. Furthermore, because of the complexity of the products, their development is also extremely costly. For these reasons radical innovations are difficult to develop in the industry. At the same time, digital technologies evolve fast and they are increasingly adopted from other industries, particularly from consumer sectors, where the demand for them is more elastic, creating pressure to embed them in existing products (Yoo et al., 2012).

The roles of customers and users are easy to distinguish from each other in the B2B setting making it a suitable setting for investigating their contributions to radical innovation. Since the extant literature rarely makes the difference between customers and users this provides an opportunity to generate new insights on the issue of how they may influence radical innovation. In the study, interviews were conducted in three incumbent companies that produce complex

technical products and that are concerned with digital innovation because of its recent diffusion into the industry. Based on the interview data collected in the study, several observations about the differences between customers and users and how knowledge from them may influence innovation can be made. These observations that are collected in Table 20.

Table 20. Differences between customer knowledge and user knowledge.

	Customers	Users
Type of knowledge	Mostly explicit	Mostly tacit
Knowledge sources	Distributed	Individuals
Guidance for innovation	Short-term changes in market needs	Long-term vision for digital innovation
Innovation goals	Mostly incremental improvement of existing products and services	Introducing radically new products and services and improving existing ones
Examples of knowledge categories	Feedback on ongoing projects, improvement suggestions, problems with existing products, new industry requirements	Usability, user experience, understanding work contexts and practices, future needs
Methods to acquire knowledge	Feedback meetings, management meetings, sales meetings	On-site user studies, use of front-line employees, prototyping
Methods to distribute knowledge	IT systems	User-insight workshops, informal cross-functional interactions
Methods to use knowledge	Product specification lists, roadmaps	Internal scenario work, collaborative research projects
Challenges	Convincing customers of the value of new innovations; rapid pace of changes in needs	Difficulty in contacting users; restricted access to usage data because of privacy concerns

To reduce market uncertainties and develop innovations with more demand, the companies studied are found to interact both with their customers and users to learn about their needs and priorities. Customers here refer to those making the purchasing decisions, such as managers from the purchasing function. Users are such individuals as ship captains and production plant operators. What is found is that these two sources differ in terms of the type of knowledge that can be received from them as well as knowledge contents. Customers are found to be an important source of knowledge on short-term changes in the market needs. This knowledge concerns feedback on ongoing projects, improvement suggestions, problems with existing products, and new industry requirements. Knowledge from customers is found to be mostly in explicit form, that is, codified in textual or numeral form and easily transmittable. Users, in contrast, are considered a source of tacit knowledge about usability, user experience, work contexts and practices, and future user needs. The tacitness implies that the knowledge resides in the individual users' plans, skills, and habits or their work community's culture, experiences, and routines. Since it is embedded in the users and their work practices, it is difficult to express in and explicit form or transfer from one person or group to another (Cavusgil et al., 2003; Nonaka, 1994; Polanyi, 2012; Smith, 2001).

Because of the differences in the knowledge types, different knowledge management methods are needed to interact with customers compared to users (see Table 21). This applies to different knowledge management tasks: acquisition of the knowledge, distributing the knowledge to relevant parts of the organization, and using the knowledge, that is, integrating it in the innovation process. Customer knowledge is acquired through meetings with

representatives at various levels of the customer's organization, distributed via IT systems, such as CRM systems, and can be translated into product specification lists to guide development activities. Acquiring user knowledge, on the other hand, requires an approach that could be described as anthropological: studying how the users work by the means of observations and interviews and testing reactions to early prototypes. Since the knowledge is difficult to codify and distribute in IT systems, face-to-face interactions are important for spreading it. Furthermore, its benefits arise from building future scenarios and use cases, and providing good starting points for larger collaborative research projects.

Since the customers are not able to help guide the development of radical innovations, the companies under study focus on the users. Although the limited numbers of users and restricted access to them make knowledge acquisition difficult, efforts to understand individual users are considered important. The companies aim to understand the users' work context and latent needs. This knowledge is then translated to future scenarios, which helps provide long-term goals for innovation projects. These goals may help companies focus their innovation activities and seize the opportunities for radical innovation that the fluid phase of the industry offers. Therefore, when little relevant knowledge is available from the customers, effort is exerted to gain access to users, acquire knowledge from them, and distribute and use the knowledge in ways that promote the development of radical innovations.

To conclude, the study reveals that in the context of digital technologies and B2B manufacturing industry, there are evident differences in how the studied companies leverage customers and users for innovation. Knowledge from customers is valuable for incremental improvements of existing products and services but their input does not help companies seize opportunities for radical innovation. The study contributes to discussion on customers and users in radical innovation by suggesting that in some contexts this distinction might explain why orientation towards downstream stakeholders may benefit the radical innovation processes of some but not all companies. It further explains these different effects by the knowledge type and contents available from customers and users and identifies managerial practices associated with the respective knowledge sources.

Table 21. Practices related to customer knowledge and user knowledge.

Category	From	Practice	Description	Purpose	Type of knowledge
Acquiring knowledge	Customers	Feedback meetings	Meetings with customers mid-project to evaluate progress and confirm direction.	Gathering feedback from customers on works in progress.	More explicit
		Sales meetings	Ongoing discussions with customers to keep up with their changing needs.	Learning about new product requirements and problems with existing products.	More explicit
		Management meetings	Regular meetings with important customers' management.	Understanding the customer's big picture and long-term goals.	More explicit
	Users	Use of front-line employees	Using maintenance staff and field service engineers as knowledge sources; hiring R&D employees with user backgrounds.	Understanding workflows and the usability of current products without involving the users themselves.	More tacit
		On-site user studies	Visiting users at their workplaces; interviewing and observing the users.	Empathizing with users; identifying latent user needs; understanding work context and work practices.	More tacit
		Prototyping	Demonstrating new concepts with tangible prototypes.	Demonstrating and discussing novel products and features.	More tacit
Distributing knowledge	Customers	IT systems	Updating new customer knowledge into, for example, a CRM system.	Bringing relevant parties up to date on changes in customer requirements.	More explicit
	Users	User-insight workshops	Regular internal workshops to disseminate user knowledge throughout the company.	Making the most of the limited access to user knowledge; sharing information about users.	More tacit
		Informal cross-functional interactions	Encouragement for ad hoc discussions; open cross-functional workspaces.	Promoting the sharing of user knowledge across organizational functions.	More tacit
Using knowledge	Customers	Product specification lists and roadmaps	Compiling customer requirements and user requirements into specification lists.	Setting goals for new development projects.	More explicit
	Users	Internal scenario work	Building future scenarios that describe trends and future use cases.	Creating explicit goals and vision based on tacit user knowledge.	More tacit
		Collaborative research projects	Future-oriented research projects with research institutes and other firms on technologies and ways of working.	Leveraging external organizations to help envision future scenarios.	More tacit

6.2 Article 2: “Can supplier innovations substitute for internal R&D? A multiple case study from an absorptive capacity perspective”

In Article 2, the interest is in how companies may substitute internal R&D with supplier innovations. It is often thought to that a company which engages in inbound open innovation needs to have significant internal R&D activities (Dahlander & Gann, 2010; Hung & Chou, 2013). It is argued that without internal R&D, external knowledge cannot be understood well enough to be exploited commercially (Cohen & Levinthal, 1990). Consequently, it would not be possible for companies with low R&D intensity to leverage their suppliers' innovation potential in developing new products and services. There is, however, a lack of empirical studies which investigate inbound open innovation activities by low R&D intensity companies. Article 2 takes a step in filling this gap by studying how the components of a company's absorptive capacity – acquisition, assimilation, transformation, and exploitation – manifest themselves in substituting internal R&D with supplier innovations. The main findings are expressed in the form of four propositions.

Four radical supplier innovation projects managed by a multinational energy company, Fortum, were investigated. The projects are referred to as Case Heat, Case Solar, Case Bio, and Case Carbon. Each of the project included a supplier with a significant innovation role, referred to as suppliers Bravo, Charlie, Delta, and Echo, respectively. By interviewing relevant managers at both Fortum and the supplier companies, case descriptions of each project were formulated. The descriptions were then were matched with the four absorptive capacity capabilities. Particular attention was paid to the management methods and organisational capabilities used to promote the projects and overcome challenges, and the roles of Fortum and its suppliers in different project phases. Afterwards, the individual cases are shortly introduced. Next, the individual cases are introduced.

Case Heat was about developing an intelligent heating control system, which reduces the heating costs of private households by giving the occupant the means to monitor and optimise their energy consumption and choose the desired heating methods. The system continuously monitors the price of electricity and compares it to heating oil prices, and chooses the cheapest way to heat the house. The project started at an initiative of Fortum who identified a business opportunity in the consumer market and was implemented in collaboration with a start-up who was proficient in relevant technological solutions.

In the acquisition phase, Fortum was interested in extending its business in the in-home energy management market. Consequently, it scanned suppliers with relevant technological solutions from Europe and the US and ordered sample products for testing. Based on promising tests and geographical proximity, collaboration with Bravo was initiated. Fortum, however, was not proficient in the technology and therefore did not aim to assimilate it. Instead, Fortum put effort in reducing market uncertainties whereas Bravo continued to develop the technology.

In the transformation phase, a couple of complications emerged. First, the parties had different visions of the customer needs which needed to be resolved. Second, Bravo, as a small start-up, was not able to process the complex contracts that Fortum put forward. Third, there were tensions over the division of risks, which were in the end resolved by agreeing on a close partnership model. In the end, the product was exploited successfully. It is marketed and sold under Fortum's brand while Bravo is in charge of the installations and operations. Fortum is able to leverage the product in its other business areas by linking it with consumer electricity sales contracts. It was also agreed that Bravo was also allowed to commercialise the technology through Fortum's competitors after a six-month head start.

Case Solar was about a new turnkey solar power production solution, including a new electricity service contract. Following the contemporary trends to utilise renewable energy sources, Fortum was the first company in the market to offer turnkey solar kits including the needed technologies, consultation, and installation. The project was based on the technological solution developed by a start-up supplier, Charlie.

Fortum had an interest in having a bigger role in the renewable energy sector. Therefore, in the acquisition phase of the project, it carried out internal pre-studies to search for new technologies and created a technology roadmap for developing new products based on solar technologies. Based on a supplier search, Charlie was chosen based on its financial performance, technological capabilities, product and manufacturing quality, and sustainability.

Fortum did not aim to build internal competences in solar technologies and therefore there was no need to assimilate the supplier's technologies. Instead, Charlie's existing solutions were packaged into products that could be marketed for Fortum's electricity customers. There was a good fit between Fortum and Charlie as Fortum focused on creating new products and Charlie was looking for credible marketing and sales partners.

A key challenge in the transformation phase was agreeing on a business model for commercial exploitation of the technology. At first, a standard Fortum supply contract was used as a basis for commercialisation. Later, the contract was significantly modified several times to refine and resolve issues related to the business model. A significant size difference between the companies was suggested as an explanation for the difficulties as Charlie did not have much resources to invest in the contract negotiations.

The technology was successfully exploited and Fortum was the first company to introduce such product in the market. After the first product a whole product family has been introduced and continuous development practices have been adopted to improve the products further. The capability to manage supplier relationships was considered to be crucial in ensuring successful collaboration with Charlie.

Case Bio was related to Fortum's sustainability agenda. The innovation was a new technology related to a power plant process that enables the refining of a sidestream of the plant's raw material into an environmental-friendly new product. In the long term, the technology allows Fortum to increase its business

revenues through the sales of a new product in business-to-business markets without an increase in the operating costs. The technology originated in a research institute which further developed it with supplier Delta. The outcome of the project was a full scale pilot power plant which validated the feasibility of the technology.

The technology in question was developed by several companies in the world but no ready solutions were available at the time Fortum became interested in it. In the acquisition phase, Fortum scanned for suppliers globally, and identified an ongoing research project formed by supplier Delta, a research institute, and a Finnish forest industry company. Fortum was not proficient in the technology and therefore it did not try to assimilate it. Instead, the project relied on complementary assets between the parties.

A close partnership was agreed on to share the significant risks related to the development of the new-to-the-world technology. Nevertheless, the costs were significantly underestimated in the beginning which created stress between the partners as Fortum became doubtful of the project's profitability in the transformation phase. Negotiation capabilities were needed to resolve the disagreements.

The project was exploited in the form of a pilot project in a full power plant scale which demonstrated the technology's feasibility. After the pilot project, Fortum went on to utilise the innovation also in other power plants but a wide-scale introduction of the end product in the B2B markets is still a work in progress.

Case Carbon aimed at implementing a new technology which captures a CO₂ sidestream from a power plant in order to reuse it. Therefore, it is a means for reducing carbon emissions. The technology was known to exist but it had not been commercialised so far and the project aimed to be the first full scale demonstration of it.

In the acquisition phase, Fortum conducted internal research on the technology and hired a consultant to help with a request for information process which aimed to identify potential suppliers of the technology. Echo was chosen from a set of around ten potential suppliers based on its good reputation. Fortum considered internal technology development to be too challenging with its limited R&D resources and hence it established a joint venture with Echo so that both of the companies could contribute to the project with their complementary strengths, Fortum being in charge of creating the supply chain needed for reusing the material and Echo of the development of the technology.

The transformation phase proved challenging as Fortum demanded technology exclusivity, which Echo was not willing to grant. Also, existing contract templates could not be used and tailor-made contracts were required to acknowledge the particularities of the new-to-the-world solution. In the end, a compromise was reached where Echo granted a preferred customer status to Fortum to compensate for the absence of technology exclusivity.

Table 22. Case summaries.

Case	Case Heat	Case Solar	Case Bio	Case Carbon
Innovation description	Intelligent home heating control system.	Residential solar energy kit.	Bio-oil production.	CO ₂ emissions reduction in power plants.
Business purpose	New product to consumer markets.	New product to consumer markets.	New product to B2B markets.	To radically reduce CO ₂ emissions in Fortum's power plants.
Innovation novelty	New-to-the-market product.	New-to-the-market product.	New-to-the-world application of an existing technology.	New-to-the-world application of an emerging technology.
Supplier size	Small	Small	Large	Large
Acquisition	Global supplier scanning. Ordering of sample products. Main selection criteria: technology, geographical location. No existing knowledge of the supply market.	Internal pre-studies. Creation of a technology roadmap. Technology and supplier search. Main selection criteria: technology, sustainability, financial performance, production quality. Some existing knowledge of the supply market.	Global supplier scanning. Main selection criteria: technology, familiarity. Some existing knowledge of the supply market.	Internal research. Use of external consultants in RFI process. Main selection criteria: technology, partner qualities. No existing knowledge of the supply market.
Assimilation	No intensive technological knowledge exchange. Fortum's current organisation has no expertise in the technology. Complementary roles of Fortum and the supplier.	No intensive technological knowledge exchange. Fortum's current organisation has no expertise in the technology. Complementary roles of Fortum and the supplier.	No intensive technological knowledge exchange. Fortum's current organisation has no expertise in the technology. Complementary roles of Fortum and the supplier.	No intensive technological knowledge exchange. Fortum's current organisation has no expertise in the technology. Complementary roles of Fortum and the supplier.
Transformation	Main issues: customer needs, suitable contracts, division of risks, partnership model. Specific challenges in negotiations: contract mode, division of risks. External and internal knowledge bases complemented each other, but technological knowledge was not combined.	Main issues: suitable contracts, business model. Specific challenges in negotiations: supplier's limited resources for negotiating, contract mode for companies of different sizes. External and internal knowledge bases complemented each other, but technological knowledge was not combined.	Main issues: division of risks, partnership model, business exclusivity. Specific challenges in negotiations: increased commercial risk due to supplier's underestimated development costs. External and internal knowledge bases complemented each other, but technological knowledge was not combined.	Main issues: suitable contracts, business exclusivity. Specific challenges in negotiations: creating a new contract template for a new business model, IPR ownership. External and internal knowledge bases complemented each other, but technological knowledge was not combined.
Exploitation	Introduction of a new product. Close collaboration.	Introduction of a new product. Close collaboration. Continuous development.	Building a full scale pilot power plant.	Cancellation before commercialisation. Close collaboration.
IPR ownership	Supplier	Supplier	Supplier	Supplier
Outcomes	New business model and product sales to residential customers. New revenues, business model, and reference product for Bravo.	New revenues, business model, and technology competence for the buying company. Supplier: new revenues, reference product, and business model.	Successful pilot. Delivery project is delayed and still ongoing. Potential new revenues for Fortum; a reference product for Delta.	Not commercialised. A new business concept for the whole value chain. New competences for the buying company.

The project was only partly exploited as it was cancelled before the commercialisation phase, due to a change in Fortum's strategy. It was nevertheless considered successful by the interviewees, since it started from an internal small-scale research project and concluded with a mature business concept including the whole value chain for the new technology.

Based on the interviewees' responses about how the projects advanced, which management methods and capabilities were used to manage them, what kind of challenges were faced, and what the roles of Fortum and the suppliers were, an overview of how Fortum substitutes its internal R&D with supplier innovations can be constructed. Notable similarities are identified with respect to the manifestations of the four absorptive capacity constructs: acquisition, assimilation, transformation, and exploitation across the cases (Table 22). By comparing the manifestations of the capabilities in Fortum's supplier innovation projects to the literature on absorptive capacity that has focused on high R&D intensity contexts, it is possible to formulate propositions on how supplier innovation projects may be managed in a low R&D intensity context.

First, by looking at the acquisition phase it can be concluded that Fortum is able to identify and gain access to relevant external technological knowledge. While in two cases (Solar, Bio) there were some existing knowledge about the supply market and its opportunities, investments in learning about new technologies were an important antecedent of the open innovation processes of all four cases. Extant literature on absorptive capacity, however, suggests that without prior investments in related knowledge, the acquisition capability of organizations is limited (Cohen & Levinthal, 1990). It is argued that without prior knowledge, organizations are not able to recognize the value of new knowledge (Todorova & Durisin, 2007). The cases, nevertheless, suggest that acquisition of external knowledge can take place even without extensive prior knowledge by the means of proactive efforts to scan potential suppliers for innovation opportunities. The ability to successfully carry out such efforts has previously been conceptualized as supply market intelligence (Handfield et al., 2009; Zsidosin et al., 2015). Based on these thoughts, the first proposition is formulated:

Proposition 1: When the buyer firm has low R&D intensity, sufficient knowledge and understanding about the acquired technology need to be gained before starting the open innovation process. Supply market intelligence is an important capability for supporting this process.

Much of the absorptive capacity literature takes it for granted that a capability to assimilate the external knowledge or technology is a prerequisite to exploiting open innovation (Cohen & Levinthal, 1990; Lane et al., 2006; Todorova & Durisin, 2007; Volberda et al., 2010). The logic is that assimilation requires in-depth understanding of the technological area since without related competences new knowledge cannot be analysed, processed, and interpreted (Zahra & George, 2002). However, the projects examined in this study sharply contrast this assumption. Fortum did not aim to assimilate its suppliers' technological knowledge in any of the four cases since maintaining and

developing the technology would have required significant investments in internal R&D. Fortum brought to the projects its knowledge of the target customers and markets, commercialization capability, and supply chain management capability. By combining these assets with the suppliers' technological assets it was able to bring together complementary capabilities and resources that are needed to develop and launch new products. The assets were, however, kept in separate organizations. Intensive technology exchange was not required in any of the cases, Fortum did not develop internal expertise in the technologies, and complementarities played significant roles in their implementation, and thus the second proposition is formulated as follows:

Proposition 2: When the buyer firm has low R&D intensity, joint innovation with suppliers is based on complementary assets and the buyer does not need to assimilate the supplier's technology.

The literature describes transformation as an internally-focused capability which aims to combine new acquired and assimilated knowledge with the organization's existing knowledge base (Zahra and George, 2002). Because no assimilation took place in the studied projects it turned out that transformation relies on interorganizational abilities. The combination of new and existing knowledge, in this context, means the coordination of the interests and views of the two collaborating parties. In all four cases, Fortum and the suppliers carried out extensive and challenging contract negotiations for transforming the complementary capabilities into joint commercial business models. In the end, close partnerships were formed (in contrast to transactional arm's length relationships) in all cases. Conflicts emerged related to the sharing of risks and rewards, agreeing on the commercial vision related to new products, and finding collaborative business models. The findings also suggest that small supplier companies may need help in the transformation phase as their ability to process heavy contracts is limited.

Although the manifestations of the transformation capability in the cases differ from what is typically described in the literature, there are nevertheless also significant similarities. The empirical findings are consistent with the descriptions which discuss transformation as the ability to create new business models (Vanhaverbeke et al., 2008) and to consider the "consequences of changing market demands in terms of new products and services" (Jansen et al., 2005, p. 1014). They are also in line with a recent suggestion that the transformation phase includes decisions on the rules and objectives that govern the development of a market-ready product based on a new technology (Patterson & Ambrosini, 2015). As all four cases in the study demonstrate the importance of negotiating and contracting capabilities for transforming the complementary capabilities to joint commercial business models, the next proposition is formulated as follows:

Proposition 3: When the buyer firm has low R&D intensity, agreements on commercial visions and business models need to be reached before a joint innovation with suppliers can be commercialised. In this process, negotiating

and contracting capabilities are important for promoting the resolution of conflicting views.

Exploitation can be described as a firm's internal effort for incorporating the new knowledge into the company's business and for introducing new products (Zahra & George, 2002) and as the fine tuning of business models and expectations to adjust to market changes or new knowledge (Demil & Lecocq, 2010; Poulymenakou & Prasopoulou, 2004). Similarly to the findings on the transformation capability, the findings on the exploitation capability suggest that when a buyer and its suppliers aim for different parts of the value chain, exploitation is a collaborative effort, which benefits from intensive collaboration in the form of close partner relationships. As Fortum does not have proficiency in the new technologies, the suppliers have a central role also in running the operations related to the new products. Close relationships are needed to motivate the suppliers to the continuous development of the products since Fortum is not able to further develop the technologies by itself. To conclude, in all cases, close collaborative relationships were considered important for the exploitation of the technologies because the utilisation of complementary capabilities required the tight integration of the operations and aligned interests. Therefore, it is proposed that:

Proposition 4: When the buyer firm has low R&D intensity, the buyer and the supplier need to have congruent interests and collaborate closely in commercialising the innovation. In this process, supplier relationship management and collaboration capabilities are important for ensuring fluent operations.

By comparing these four propositions with the well-known absorptive capacity model by Zahra & George (2002), it is possible to suggest what an absorptive capacity process might look like when a low R&D intensity company substitutes its internal R&D with supplier innovations (Figure 5). Based on the observations from the four cases of the study, it is proposed that in the low R&D context there are idiosyncrasies in all four capabilities of the absorptive capacity. Since the focal firm has limited prior knowledge of the acquired technology, major efforts are required for gaining the sufficient knowledge about the new field before starting the open innovation process. It is also found that introducing radical innovations based on suppliers' technologies is possible without high assimilation capability making it possible for low R&D companies to benefit from radically novel external technologies. In the low R&D context, transformation does not include merging incompatible technological knowledge sets, but instead focuses on reaching an agreement on how the technologies should be commercialised. Exploitation, in turn, is more complicated in the low R&D context since it is a collaborative effort with the supplier.

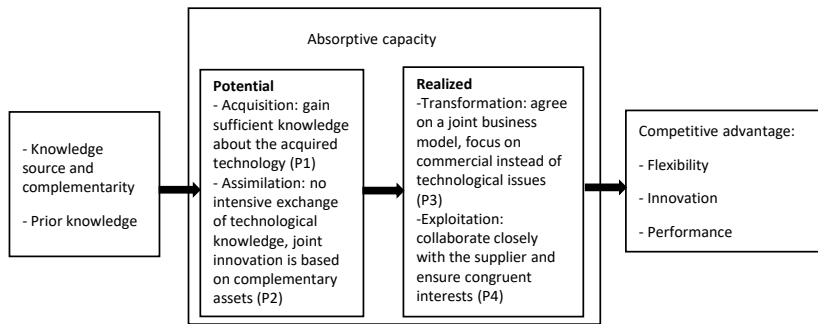


Figure 5. The proposed absorptive capacity process in the low R&D intensity context.

Furthermore, the results suggest that there are capabilities related to supply market intelligence, negotiating and contracting, and supplier relationship management and collaboration which are beneficial for managing such inbound open innovation processes with suppliers in a low R&D context. All of these capabilities fall into what has been called *supplier management capabilities* in the extant literature. In the past studies, it has been suggested that supplier management capabilities, such as the abilities to manage supplier relationships, supplier risks, and supplier development (Day & Lichtenstein, 2006; Foerstl et al., 2010; Reuter et al., 2010), are needed to establish and manage successful buyer-supplier relationships (Wagner & Boutellier, 2002). According to the empirical findings of this study, different supplier management capabilities are needed in different phases of the absorption process. Supply market intelligence capability is needed at the acquisition phase, negotiating and contracting capabilities in the transformation phase, and supplier relationship management and collaboration capabilities in the exploitation phase. The study therefore takes a step in filling the gap in the current understanding of the processes and policies that firms can use to manage the use of external knowledge sources in low R&D contexts (Lane et al., 2006).

To conclude, it is often thought to be necessary that a company which engages in inbound open innovation has significant internal R&D activities (Dahlander & Gann, 2010). It is thought that without internal R&D, external knowledge cannot be understood well enough to be exploited commercially (Cohen & Levinthal, 1990). The findings of this study challenge this view and present an alternative approach to how open innovation may be used to introduce radical innovations, which does not depend on high levels of internal R&D. This approach is based on close collaboration with a supplier with valuable knowledge throughout the innovation life cycle — not merely at the beginning. The external knowledge is not fully integrated into the company and therefore modest levels of related knowledge are sufficient. Instead of integrating the knowledge, it is retained by the supplier, which is given high responsibilities in further developing the initial technology and participating in the day-to-day operations after the product launch.

6.3 Article 3: “Absorbing radical ideas from unusual sources – the role of social integration mechanisms”

Article 3 investigates how radical ideas advance in an organization called Steel Inc. through different development phases from invention towards commercialization. It identifies social integration mechanisms which promote and hinder this process. It focuses two radical ideas that originate from unusual sources: a technical employee within the company and an external inventor. These sources can be considered unusual since practically all of the ideas in the studied steel company originate from its R&D unit or a stable set of partners such as universities and research centres. Insights from this research setting are potentially valuable for companies aiming to develop radical innovations as the literature suggests that incumbent companies rely too strongly on internal R&D and their usual partners in finding radical ideas (Birkinshaw et al., 2007; Bunduchi, 2013; Chang et al., 2012; Stringer, 2000). The radicalness of the ideas and the lack of familiarity with the inventors is considered to create a context of high uncertainty which may make their absorption difficult (Chesbrough, 2006). This specific context is, however, poorly understood which motivates research on it. Next, the two projects (based on the ideas) are shortly introduced and the main findings of the study are presented. General information on the projects is collected in Table 23.

Table 23. Project information.

	Project 1	Project 2
Inventor	Engineer (internal idea)	Entrepreneur (external idea)
Innovation type	Process innovation that enables new products	Process innovation that enables new products
Innovation novelty	Radical (new-to-the-world)	Radical (new-to-the-world)
Outcome	Successful adoption of a new process led to the introduction of multiple new products.	Failure: rejected by the R&D unit

The first idea was discovered by an engineer within Steel Inc. He had a long history within the company and consequently good contacts to a number of people in different functions, both to blue-collar workers and managers. At the time of the studied invention, he was working as a supervisor in the quality control function. The invention was about a new technique in steel manufacturing which he believed could lead to new products with greatly enhanced properties. He faced initial difficulties in convincing managers of the idea's feasibility. Finally, after several dismissals, he managed to convince the head of the R&D unit to take a closer look. The head of the R&D unit made calculations based on the idea and concluded that while it might work it was too risky as the manufacturing equipment might be unsuitable for testing it. The inventor, nevertheless, persistently continued to promote the idea to other managers. After some time, he managed to arouse the interest of an R&D manager responsible of product design. Next, the manager started to contact others and eventually a team emerged to promote the idea in secret as it did not have an official project status. In addition to the abovementioned R&D manager the team included another R&D manager with long experience of working with a certain production line, and a product manager from the sales organization.

They decided to leverage their positions in the organization and conduct manufacturing tests in secret. The tests were promising and the idea started to get wider support within the organization. After this success, the product manager started campaigning for the idea to be acknowledged by the top management. Subsequently, it was granted a formal project status and development resources and the technique was further studied and developed. At first, the resulting new product was sold to existing customers as an improved version of an existing product. The new technique was able to improve product quality while lowering production costs. Finally, the project led also to the creation of multiple new products. To fully capitalize on them the company moved to new markets both in terms of industry and geography.

The second idea was proposed by an entrepreneur who operates a small company that produces steel-based products. He had invented a new method of steel manufacturing that he considered to have high potential. He, however, understood that he would not be able to exploit it by himself in a large scale. Therefore, he contacted the CEO of Steel Inc. who got interested in the idea and commissioned the R&D unit to investigate its potential. The initial reception of the idea was positive. Its potential was evident and applications could be found from many areas. An R&D director told that while it was apparent that the inventor did not have much education it was obvious that he knew what he was talking about. There were, however, doubts about the technology's feasibility and fit into the company's product portfolio. The idea did not get an official project status. Instead, it was at a pre-evaluation stage of the company's innovation process. The idea was, however, not able to evoke much interest within the R&D unit. Nobody was personally committed and motivated to study it and it was overshadowed by other projects with clearer agendas and deadlines. Several academic studies were found which supported the inventor's arguments but the R&D employees were suspicious that he might have exaggerated its potential. It was concluded that manufacturing tests would be likely to provide more information, but that they are too expensive to conduct. There was no one to promote the idea within the R&D unit and no such tests took place. For some time, it remained at a pre-evaluation stage with low priority but, in the end, the investigations were shut down.

The analysis of the projects includes two parts. First, the project phases are divided according to four absorptive capacity capabilities: acquisition, assimilation, transformation, and exploitation (Zahra & George, 2002). The level of each capability are assessed for both of the projects to evaluate how different aspects of the company's absorptive capacity perform. Then, social integration mechanisms and their relations to the capabilities are identified to find potential connections between the mechanisms in use and the company's absorptive capacity.

The assessed capability levels are collected in Table 24. Based on the assessments, it seems that the absorptive capacity of the company does not fully support the integration and use of radical ideas from unusual sources. Especially assimilation and transformation capabilities seem to perform poorly.

While only the internally generated idea had problems in the acquisition phase, both ideas faced significant resistance in assimilation and transformation. High uncertainties over the feasibility of the technologies and their incompatibility with the company's prevailing capabilities and business scope made assimilation very difficult. Assimilation attempts were nevertheless necessary for increasing understanding of the ideas and initiating company-wide transformation efforts as the interviewees considered concrete test results to play a key role in gaining wider support for the ideas. Project 1 was, in the end, able to advance through these phases and achieve significant commercial success, whereas project 2 suffered from a lack of serious assimilation attempts and was not able to proceed beyond the pre-evaluation stage. While the study does not include explicit comparisons to other kinds of projects, the studied company has successful ongoing collaboration partners such as with universities and research centres and the interviewees suggested that there were idiosyncrasies in these two projects which explain difficulties in their absorption.

Table 24. Absorptive capacity capability levels in the studied projects.

Absorptive capacity capability	Project 1	Project 2
Acquisition	Low The idea originated from within the company and was acknowledged after the persistent initiatives of the innovator.	High An entrepreneur contacted the case company CEO with a new steel manufacturing method. There were no previous relations between the parties.
Assimilation	Low The unusual source of the idea and the inventor's lack of technical expertise delayed its analysis. Uncertainties regarding the idea's potential and feasibility hindered the use of manufacturing tests as an analysis method.	Low Non-disclosure agreement limited informal discussions about the idea and impeded idea development. Because of low priority, only theoretical analysis was performed. Metallurgical analysis and manufacturing tests were not conducted.
Transformation	Medium Initially the idea was not able to challenge existing cognitive structures. Later, the organization was convinced by thorough analysis of the new manufacturing technique, the outcomes of the manufacturing tests, and the credibility of the project team. This generated a search of new application areas which transformed how the company saw its business scope and strengths.	Low Existing perceptions of the company's scope and capabilities remained dominant. The idea was considered incompatible with them and was rejected.
Exploitation	High The innovation was used to provide better quality products with lower costs in an existing product group. In addition, a new product group was established and a new market created around it.	Low The case company did not try to exploit the idea. The inventor continued to work with the technology under his own small business.

The second part of the analysis focuses on the role of social integration mechanisms in the absorption processes. All three categories of social integration mechanisms that have been identified in the literature (Van den Bosch et al., 1999) were found to influence the studied projects: 1) socialization mechanisms that create tacitly understood rules for appropriate action, 2) coordination mechanisms that facilitate knowledge exchange across

disciplinary and hierarchical borders, and 3) systems mechanisms that control organizational behaviour via the means of manuals, policies and procedures (Jansen et al., 2005). A summary of these findings can be found in table 25.

The literature suggests that socialization mechanisms such as shared work background, similar education, shared norms, values, and beliefs, and the use of specific technical language between the members of an organization are beneficial as they reduce conflicts, facilitate communication and comprehension, and increase trust, and hence improve its efficiency (Jansen et al., 2005; Todorova & Durisin, 2007; Zahra & George, 2002). Similar mechanisms were found to facilitate the operations of the R&D unit in the studied company. The findings, however, suggest that the same socialization mechanisms that make the R&D unit function efficiently may be responsible for its tendency to reject ideas from unusual sources. The interviews suggest that downside of a highly-socialized community is that it may induce a bias against ideas from outside of it. Members of the R&D unit may consider ideas from their close colleagues and contacts more credible because they originate from a source they trust and are formulated in a way that they understand well. This bias is widely called the not-invented-here syndrome in the literature (Antons & Piller, 2015; Cohen & Levinthal, 1990; de Araújo Burcharth et al., 2014; Katz & Allen, 1982) and the empirical findings from the study trace its origins to strong socialization mechanisms. The interviewees also reported that the company's organizational culture includes norms and values which do not support risk-taking, and therefore radical projects with high uncertainties may have a low likelihood of getting accepted.

Systems mechanisms are found to negatively influence the absorption of the ideas. A non-disclosure agreement was signed to protect the idea in project 2 and it eventually turned out to be a major reason behind its rejection. The non-disclosure agreement limited discussions of the idea to a group of seven people and greatly restricted available expertise for its evaluation and development in the assimilation and transformation phases. Furthermore, strong formalisation increased the projects' reliance on other social integration mechanisms. Strict requirements for project proposals were considered to fit poorly with the high uncertainties associated with radical ideas. According to a vice president in the company: *"The dilemma is that if you have a technological idea without a sophisticated commercial vision, it is very difficult to mould it into something that would pass the decision gates."* The idea in project 1 did not fulfil the selection criteria until late in its development and did therefore not have official project status and development resources during its most critical stages. Project 2 was in a pre-evaluation stage where it relied on the initiative of the R&D employees but was not governed by a time allocations or deadlines.

Whereas socialization and systems mechanisms were found to hinder the absorption of the ideas especially in the assimilation and transformation phases, coordination mechanisms appear in a different light. The findings suggest that when integrating radical ideas from unusual sources, the company is reliant on coordination mechanisms. Knowledge transfer practices and cross-functional interfaces in use in the organization as well as project 1's inventor's job rotation

experience and links to individuals with boundary-spanning abilities seemed to have important roles in connecting employees from different parts of the organization. With the help of such mechanisms, a wide range of expertise could be leveraged to analyse the ideas. Furthermore, after successful manufacturing tests in project 1, the good news spread very quickly throughout the relevant organizational functions, such as R&D, production, sales, and marketing due to interfaces which promote cross-functional knowledge exchange, and this helped grow the coalition to promote the idea. A vital part of the team in project 1 was a product manager who acted as a boundary spanner across functional borders. He had deep understanding of the informal power structures within the organization and was able to formulate the message in appropriate terms for each recipient. He was important in facilitating interactions with associated functions after the manufacturing tests and was later mainly responsible for convincing top management of the idea, which contributed greatly to the transformation capability.

Table 25. Social integration mechanisms in the studied projects.

Social integration mechanism	Project 1	Project 2	Related absorptive capacity capability
Socialization mechanisms			
Connectedness	Wide networks within the organization helped the inventor recruit supporters.	Lack of connections between the inventor and the company prevented interactions.	Acquisition, assimilation
Shared language, background, and education	Lack of shared technical language between the inventor and the R&D managers decreased trust and credibility and limited knowledge exchange on the idea. Shared backgrounds and language increased trust and facilitated knowledge exchange among the R&D employees.	Lack of shared technical language between the inventor and the R&D managers decreased trust and credibility and limited knowledge exchange on the idea.	Assimilation, transformation
Values and norms	Values and norms were dominated by conservativeness and risk aversion which were obstacles for uncertain ideas.		Assimilation, transformation
Coordination mechanisms			
Practices for knowledge transfer	Open door policy and coffee room discussions promoted informal knowledge exchange across functions.	Knowledge transfer practices could not be used due to privacy concerns.	Assimilation, transformation
Cross-functional interfaces	Strong links between organizational functions facilitated market launch.	Idea development was conducted within the R&D unit.	Transformation, exploitation
Job rotation	Helped the inventor form valuable links throughout the organization.	No mentioned benefits from job rotation.	Acquisition, assimilation
Boundary spanners	Project team member with good social skills and networks across functional borders helped create credibility for the idea.	No boundary spanners.	Assimilation, transformation, exploitation
Systems mechanisms			
Formalisation	Idea selection criteria disallowed highly uncertain ideas.	Non-disclosure agreement prevented wide-scale knowledge exchange.	Assimilation, transformation,

The findings hence suggest that coordination mechanisms are valuable in benefiting from radical ideas from unusual sources. Coordination mechanisms, which were crucial for the integration of the idea in project 1, were unavailable

for project 2, which arguably influenced its rejection (Table 25). The findings suggest that well-working coordination mechanisms may be beneficial and help overcome some obstacles related to the acceptance and development of radical ideas from unusual sources.

Interestingly, the findings emphasize the important role of manufacturing tests in reducing uncertainty in radical innovation projects. This is in line with studies on other process industries⁷ which suggest that in these industries manufacturing tests need to be conducted very early in the innovation process (Kurkkio et al., 2011; Pisano, 1997). Because of the high technological uncertainties associated with the investigated projects, theoretical studies and laboratory analyses were only of limited use. Conducting manufacturing tests to test a radical idea in practice was proposed as an effective, although costly, way to reduce uncertainty. Successful manufacturing tests were suggested to have an important role in the legitimization of radical projects across organizational functions, as they provide tangible evidence of the ideas' feasibility. They are valuable both in understanding the ideas (assimilation) and transforming existing cognitive structures related to technologies and the company's business scope (transformation). The difficulties related to manufacturing tests might partly explain why radical innovations have been found to be rare in the process industries (Utterback & Abernathy, 1975).

The findings on project 1 suggest that these difficulties can be overcome if a team emerges to promote the project in secret without official approval. Such a team is suggested to benefit from composition which includes members who have sufficient knowledge and resources in their control to advance the project, and a boundary-spanner who is able to convince relevant decision-makers in various parts of the organization. Dense connections between the inventor and the rest of the organization were considered beneficial in the formation of such team as the inventor was able to present the idea to multiple employees in R&D positions despite of many rejections. Some of the ties were strengthened by social relationships outside the work context. In contrast, the inventor in project 2 had very limited contact points to the case company and hence there were no opportunities to influence the idea's development.

To conclude, this study contributes to the radical innovation and open innovation literatures by investigating the mechanisms which affect an organization's ability to absorb radical ideas from unusual sources. This is highly relevant for many companies as extension to new idea sources is often suggested as a means to facilitate the development of radical innovations. The study examines social integration mechanisms – socialization, coordination, and systems mechanisms – in the absorption processes of two radical ideas. The findings suggest that radical ideas from unusual sources face high uncertainties. The radicalness of an idea brings about uncertainty as its technical feasibility may be difficult to determine and it may lack a refined commercial vision. Furthermore, if the R&D unit of a company typically relies on internally generated ideas and a stable set of external partners, the level of uncertainty of

⁷ Process industries include petrochemicals and chemicals, food and beverage, mining and metal, mineral and material, generic pharmaceuticals, forest, and steel industries (Lager et al., 2013).

ideas that are received from other sources is likely to be perceived high because the developers have limited means of evaluating the inventors' credibility. This may reduce the R&D developers' motivation to work on such ideas, hinder the availability of development resources, and sometimes lead to the outright rejection of the ideas. Consequently, many of the social integration mechanisms that are usually beneficial for innovation may be incompatible with such ideas and cannot be benefited from. Especially strong reliance on formalisation and socialisation within the R&D unit may work against ideas which are characterised by high uncertainty. In contrast, coordination mechanisms, which promote interactions between different parts of the organizations may promote their absorption.

6.4 Article 4: “Going the extra mile: Managing individual motivation in radical innovation development”

Article 4 investigates radical innovation management from the point of view of work motivation. Extant studies on radical innovation have noted the importance of employee motivation, but there has been few studies which address how managers may influence it (Alexander & van Knippenberg, 2014; Kelley et al., 2011; O'Connor & McDermott, 2004; Stringer, 2000). While there exists a rich literature on employee motivation towards work tasks, the question of how its insights may be applied to the context of radical innovation is not well understood. To address this research gap, propositions on how managers may influence the initial level of individual motivation and its effect on the success in development tasks is formulated and a research model is built based on them (Figure 6). The propositions are formulated by combining insights from work psychology literature and radical innovation literature. Especially two influential work psychology theories – goal-setting theory (Locke & Latham, 1990) and social cognitive theory (Bandura, 1997) – are drawn from for building the foundation for the propositions and the model. To provide a rich understanding of the studied phenomenon, the model positions its elements at multiple levels: individuals, project teams, and the organization. The elements of the model include forms of goal-setting and organizational support, individual motivation, and success in radical innovation work tasks.

The value of the model is that it brings together characteristics of radical innovation development that make it challenging for individual developers to maintain their work motivation. Because of the high levels of uncertainty, finding solutions to radical innovation problems is difficult. Based on the extant literature, several such difficulties are proposed. First, the developers are required to have extensive skills and maintain an intensive effort throughout the development processes. Developing radical innovations is therefore highly demanding both in terms of cognitive tasks and workload. Second, the high uncertainty that characterizes the development processes of radical innovation projects manifest itself in long project times and non-linearity. Therefore, the developers have to endure unanticipated findings, setbacks, and changes of direction, and therefore have to have a high tolerance for ambiguity. Third,

because radical innovation projects have a low success rate, the developers face frequent failures, which can be mentally stressful. The employees may also face organizational and resource uncertainties because of the dominance of incremental innovation goals in many incumbent companies. Radical innovation developers may therefore have difficulties in legitimizing their work, receiving sufficient resources, and gaining appreciation and respect from the rest of the organizations. These difficulties listed above thus concern both practical requirements for work and social status within the work community — both of which may have detrimental motivational effects.

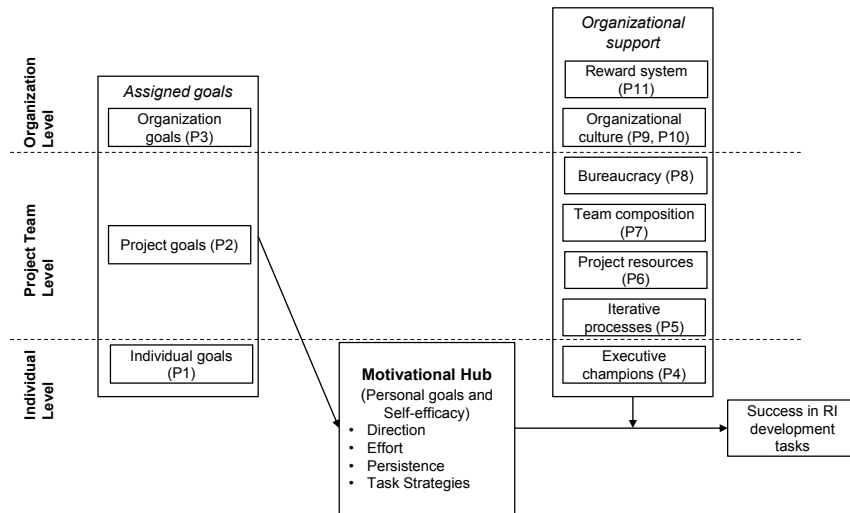


Figure 6. Model of managing individual motivation in radical innovation development.

The model includes a total of eleven propositions:

- Proposition 1. Moderately challenging goals relative to individual skills and abilities increase individual motivation for radical innovation.
- Proposition 2. A moderate level of specificity in project goals increases individual motivation for radical innovation.
- Proposition 3. Conflicting goals decrease individual motivation for radical innovation.
- Proposition 4. The involvement of experienced and skilled executive innovation champions increases individual motivation for radical innovation.
- Proposition 5. Breaking radical innovation projects into smaller sub-goals increases individual motivation for radical innovation.
- Proposition 6. Providing sufficient resources for radical innovation projects increases individual motivation for radical innovation.
- Proposition 7. A project team composition with a variety of perspectives and expertise increases individual motivation for radical innovation.
- Proposition 8. Bureaucracy decreases individual motivation for radical innovation.

- Proposition 9. An organizational culture which promotes risk-taking and tolerates failure increases individual motivation for radical innovation.
- Proposition 10. A positive organization-wide view of radical innovation increases individual motivation for radical innovation.
- Proposition 11. Rewarding developers for succeeding in radical innovation development tasks increases individual motivation for radical innovation.

The model has four main elements: i) assigned goals, ii) motivational hub, iii) organizational support, and iv) success in radical innovation development tasks. In summary, it is argued that, by assigning goals, managers may influence the level of individual motivation towards radical innovation tasks, which translates into success in development tasks if there is sufficient organizational support.

The first element, which covers propositions 1–3, reflects the idea that the way managers assign goals may influence the level of individual motivation for radical innovation development. These goals may be assigned at various levels. First, there may be goals which address the overall purpose of a company (P3). The challenge in defining these goals is that some of the goals may be in conflict with each other, which may put employees in a stressful position. Companies may, for example, aim both for radical renewal and for the improvement of their existing competencies. Motivational issues may arise if the priorities of these goals are not made clear for individual employees. At the project level, the goal-setting challenge is how to define project goals when there is great uncertainty over how the project will progress and what its outcomes may look like (P2). If the project goals are defined in too much detail, the project teams may be unable to react to unanticipated findings and adjust their actions and the direction of the project based on new knowledge. Some goals are, however, necessary to support decision-making and prioritizing between alternative actions. Finally, managers can set goals for individual developers' work performance (P1). The model proposes that special attention should be paid to the individual capabilities and stress tolerance of employees and set goals which are challenging but not overly demanding.

Next, the second element in the model proposes that individual motivation for radical innovation tasks is determined by a so-called motivational hub, which comprises two factors: personal goals, that is, "Do I want to do this?", and self-efficacy beliefs: "Can I do this?". To reach high levels of motivation, the developers hence have to be interested in the work tasks and believe that the costs of engaging in them do not exceed the rewards and enjoyment that they might generate. High interest levels may, however, not be realized in practice if the employees do not believe they have the abilities to reach their goals. Hence, both factors are needed. Personal goals and self-efficacy beliefs influence success in radical innovation tasks by i) directing attention to relevant activities, ii) determining the amount of effort, iii) influencing persistence, and iv) facilitating the search and use of task-specific knowledge and strategies. Based on the empirical data, it is found that all four of these mechanisms are valuable for success in radical innovation development tasks and that they are influenced

by goal assignment. Therefore, it may be concluded that personal goals and self-efficacy beliefs, that is, the motivational hub, mediate the effect of goal assignment on performance outcomes.

The third element of the model, which covers propositions 4–11, addresses organizational support, that is how much the organization values its employees' contributions, rewards increased work effort, provides aid to help carry out job tasks, and meets the employees' socioemotional needs (Rhoades & Eisenberger, 2002). Different forms of organizational support are treated as boundary conditions, which moderate how the initial level of individual motivation affects the success in radical innovation development tasks. Without organizational support, the employees may feel that they do not have the means to carry out job tasks and that the organization does not value their contributions. At the organizational level, culture (P9, P10) and reward systems (P11) were found relevant. If the organizational culture values radical innovation, the developers may benefit from social image gains and have feel safe in their jobs. At the project level, it is proposed that sufficient resources — both in the form of time and money (P6) as well as diverse expertise (P7) —boost developers' motivation as they strengthen the beliefs to successfully carry out the projects. Also, too bureaucratic management systems which do not acknowledge the characteristics of radical innovation projects may generate negative attitudes, as the employees feel that some procedures limit their opportunities to advance radical projects (P8). Linear stage-gate process models are an example of such a managerial element which is often associated with bureaucracy and inflexibility. Breaking the projects into smaller sub-goals is suggested to be beneficial for not only reducing technological and market uncertainties but also for providing the developers with experiences of success, thus solidifying their motivation (P5). By completing sub-goals, they may gain valuable feedback and become aware of their learning progress, which is important, as the goals in long projects may be otherwise too distant to be effective. At the individual level, experienced managers may be essential in providing socio-emotional support and reducing organizational barriers which hinder the development process (P4). Providing organizational support is therefore proposed as a way for managers to make sure that high levels of motivation actually translate into high job performance.

Table 26. Summary of empirical support for the propositions.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
Steel Inc.	S	s	S	S	s	s	S	S	s	Ss	Ss
Forestry Inc.	S	S	S	S	S	S	S	S	s	S	S
Process Inc.	S	s	S	s	S	s	S	S	s	s	S
Broadcasting Inc.	S	S	S	S	S	Ss	S	s	Ss	s	0

S = The proposition is supported directly.

s = The inverse proposition is supported by evidence.

0 = The proposition could not be observed.

In the empirical part of the study, the model described above is tested and elaborated by investigating four incumbent companies. The theory testing part includes finding instances from the interview data which suggest that the elements of the model can be found from the studied organizations and that the

propositions are supported. Table 26 shows that, except for proposition 11, support for all propositions was observed in all of the case companies.

Table 27. Examples of managerial methods to motivate individuals for radical innovation development.

Managerial action	Working mechanisms
Organization level	
Structural separation of radical and incremental innovation activities.	Resolving goal conflicts helps focus efforts. Ensuring resources for radical innovation projects increases self-efficacy.
Complementing monetary rewards with public acknowledgements.	Rewards influence personal goals by strengthening extrinsic motivation, hence increasing the attractiveness of radical innovation development.
Emphasizing past success stories. Emphasizing the learning aspects of failures.	Reduces fear of negative outcomes and encourages risk-taking.
Making radical innovation a strategic priority.	Increases purposefulness, meaningfulness and social gains from involvement in radical innovation development.
Project team level	
Assigning strategic goals to define a desired future vision.	Balancing goal clarity and ambiguity increases self-efficacy and helps guide the development towards desirable directions.
Iterative innovation processes.	Allows employees to succeed in reaching intermediate goals, which strengthens self-efficacy beliefs and helps maintain enthusiasm despite frequent failures.
Cross-functional project teams.	Diverse expertise and perspectives facilitate the search for suitable task strategies and increase self-efficacy.
Reducing the amount of bureaucracy in radical innovation projects.	Removing obstacles to radical innovation projects makes employees perceive themselves to be better equipped to succeed in their tasks.
Transparency in radical innovation activities: open communication and presentation of interim results.	Reduces goal conflicts within the organization, making it easier to direct development effort and resources.
Individual level	
Defining development tasks and workload according to each developer's skills and characteristics. Changing assignments according to the process phases.	Encourages high effort but does not incapacitate the developers.

The model is elaborated by investigating managerial actions, in use in the companies, which may be used to increase employee motivation for radical innovation development and ensure that the initial level of motivation materializes in increased job performance. These examples are collected in Table 27. These examples suggest that actions such as building separate organizational structures for radical and incremental innovation activities and implementing iterative innovation processes may influence individual motivation. While the value of most of these actions has been widely acknowledged in the literature on radical innovation (Assink, 2006; Leifer et al., 2000; Slater et al., 2014), their effect on individual motivation has not been focused on before.

In sum, the study contributes by formulating, testing, and elaborating a model that explains how managers may influence the initial level of individual motivation and its effect on the success in development tasks by assigning external goals and providing organizational support. Formulation of the model is based on a literature review on work motivation and radical innovation and it includes bridging these two research streams to present propositions that are then tested with empirical data from four incumbent companies. The study

finds support for all of the formulated propositions. Also, based on the data, the model is elaborated by providing examples of managerial actions that have been adopted in incumbent organizations that may improve individual motivation to develop radical innovations. The identification of such concrete actions enriches the model by increasing its practical relevance by relating its elements to concrete managerial actions and allowing the establishment of further linkages to existing management theory.

7. Discussion

The purpose of this section is to present the contributions of this dissertation to innovation management theory and practice. First an overview of the main findings of the articles is presented. Then, the contributions of each article are discussed individually. Then, the findings are combined to formulate a typology of managerial positions for promoting radical innovation with open innovation. Finally, the limitations of the study are addressed and recommendations for future research are presented.

In section 2, a categorization of managerial areas needed for the development of radical innovations was presented (Table 4). The main findings of the studies, structured according to this categorization, are presented below in Table 28. The findings address each of the four managerial categories related to radical innovation: processes, organizational structures, culture, and external linkages.

With regard to processes, Article 1 identified managerial practices for acquiring, distributing, and using knowledge from users that can be adopted to leverage users for radical innovation. Article 2 examined how a company may substitute its internal R&D with its suppliers' technologies, and revealed how supplier management capabilities related to supply market intelligence, negotiating and contracting, and supplier relationship management and collaboration are beneficial for managing such innovation processes.

Article 3 addresses the category of organizational structures in that it highlights the role of cross-functional interactions when absorbing radical ideas from unusual sources. According to the findings of the study, in such situations, a company's ability to integrate and use radical ideas relies on coordination mechanisms, which facilitate knowledge flows across functional and hierarchical boundaries.

The studies have three main findings related to external linkages in radical innovation management. First, in Article 1, it is found that in the context of B2B industries that are undergoing digitization, orientation towards downstream stakeholders may be useful for finding guidance for radical innovation. However, not all stakeholders are equal: customers' contributions may be limited to guiding incremental innovation whereas users can be an important source of knowledge about future directions for radical innovations. Article 2 proposes that high levels of internal R&D are not necessary for companies to benefit from their suppliers' radical technological inventions. Therefore, it is possible to substitute – not only complement – internal R&D with open innovation. Finally, Article 3 reveals that when companies extend to new kinds

of partners, which they have no previous experience of, for finding radical ideas, they may be faced with two major sources of uncertainty: idea radicalness and unfamiliarity with the idea sources. In such situations, socialization and systems mechanisms, which typically promote the development of ideas into new products, may be counterproductive.

Table 28. Overview of the findings.

Category	Definition	Main findings related to the category
Processes	Systematic ways of governing radical innovation projects from early idea stages to commercialization.	<p>Article 1: Specific knowledge management practices are needed to leverage users for radical innovation.</p> <p>Article 2: When substituting internal R&D with suppliers' radical technologies, supplier management capabilities help manage the collaborative innovation processes.</p> <p>Article 4: Innovation process models and governance methods may influence individual motivation towards radical innovation development tasks.</p>
Organizational structures	The allocation of responsibilities and resources for radical innovation development within the organization and the integration of radical innovation development with other organizational functions.	<p>Article 3: Coordination mechanisms, which facilitate knowledge flows across functional and hierarchical boundaries, are critical when absorbing radical ideas from unusual sources.</p> <p>Article 4: Organizational structures and the level of cross-functional integration may influence individual motivation towards radical innovation development tasks.</p>
Culture	Shared concepts, values, and beliefs within the organization that support radical innovation.	Article 4: Organizational culture and leadership may influence individual motivation towards radical innovation development tasks.
External linkages	Search for radical innovation opportunities from outside the organization.	<p>Article 1: In B2B industries undergoing digitization, customers may be unable to guide radical innovation, and it is beneficial to interact with users.</p> <p>Article 2: Suppliers' radical technologies may be used for radical innovation without high internal R&D investments by establishing highly collaborative arrangements with them.</p> <p>Article 3: Companies may have difficulties in integrating radical ideas from unusual sources as socialization and systems mechanisms, which may be useful in interacting with usual partners, may hinder collaboration.</p>

Article 4, which investigates individual motivation in radical innovation development, provides interesting insights to multiple categories. The result suggest that managerial actions in multiple areas – processes, organizational structures, and culture – influence individual developers' motivation towards radical innovation development tasks. As an example, iterative innovation processes may be beneficial as they break long-term innovation goals into smaller sub-goals which provides opportunities for experiences of success which may have positive motivational effects. The study does not directly examine the motivational effects of engaging in open innovation activities, which have been discussed elsewhere (cf. de Araújo Burcharth et al., 2014; Katz & Allen, 1982). Nevertheless, as the other articles argue that promoting radical innovation with open innovation may require specific processes and organizational structures, Article 4 suggests that implementing these processes

and structures may have motivational effects, and companies should, therefore, evaluate their open innovation methods also from this point of view.

7.1 RQ1: How do B2B manufacturing firms leverage customer knowledge and user knowledge for the purposes of radical digital innovation?

A major ongoing debate in the innovation management community concerns the relationship between interactions with customers and users and radical innovation (Agostini et al., 2016). Some authors argue that companies should be strongly oriented towards their customers and users in order to gain an advantage over their competitors by predicting market demand and acquiring ideas and knowledge (Chatterji & Fabrizio, 2014; Lettl, 2007; Lettl et al., 2006). In these studies, customers and users are proposed to be the most important sources of knowledge about market demand for new innovations (Bogers et al., 2010; Cohen et al., 2002; Fang et al., 2008). Others contest that locking in to the current customers limits companies' abilities to think outside the box and explore radical ideas that the customers may not yet value (Christensen & Bower, 1996; Menguc et al., 2014).

A weakness of this research stream is that typically no clear distinction is made between customers and users. The terms are often used interchangeably, even within a same study. This is understandable in B2C contexts where those who buy the products are often users themselves. Unfortunately, similar ambiguity can also be found in studies on B2B industries, where the two groups are often distinct. Based on Article 1, it is proposed that it is important to make the distinction between customers who make the purchasing decisions and users who use the innovations, since these two may benefit innovation processes in different ways.

In the B2B manufacturing industry, customers were found to be an important source of knowledge related to changes in short-term requirements regarding the functions, properties, constraints, and rationale according to which new products and services should be designed (Berente et al., 2009), hence supporting incremental innovation. However, they were found not to be able to express their long-term future needs in a situation where digital technologies have created opportunities for radical innovations and dominant trajectories for future development have not yet been established. Simply asking the customers what they want is therefore not likely to provide sufficient guidance for radical innovation. In contrast, interactions with users were considered to facilitate the development of radical innovations. By understanding their users' latent needs and the users' work context, companies may be able to envision future users' needs and usability criteria for new digital products and services. These findings support earlier research that sees users as especially valuable in radical innovation (Chatterji & Fabrizio, 2014). Based on the findings, the need to distinguish customers and users is emphasized, a distinction that has been lacking in the extant literature (Callahan & Lasry, 2004; Fuchs & Schreier, 2011; Nijssen et al., 2012; Sánchez-González et al., 2009).

The findings of Article 1 suggest that the different roles of customers and users may be explained by the type of the knowledge received from them. It is found that the companies studied are able to access explicit knowledge from their customers and tacit knowledge from their users. Consequently, they are found to use different practices for acquiring the knowledge, distributing it within their organizations, and using it for innovation. As expected based on earlier literature (Alavi & Leidner, 2001; Nonaka & Takeuchi, 1995; von Hippel, 1994), explicit knowledge is relatively straightforward to manage, but tacit knowledge requires more indirect methods, such as on-site user studies, prototypes, and workshops. These findings are valuable as they concern effective ways of acquiring and integrating external knowledge and hence address a key issue in many forms of open innovation (Azadegan, 2011; Cheng & Huizingh, 2014; Christensen et al., 2005; Geum et al., 2013; Sáenz et al., 2014). They also emphasize that external partners may vary in their knowledge contents, which influences what kind of management practices are applicable. The findings are therefore increase understanding of how to design innovation processes that enable the integration of external knowledge for the purpose of developing radical innovations.

These findings are in line with the distinction between customer-led and market-oriented philosophies by Slater & Narver (1998). They argue that the customer-led philosophy focuses on the expressed needs of customers and is therefore suitable for short-term adaptation to changes in customer needs. Market-oriented philosophy, in contrast, has its focus on understanding the *latent* needs of the customers. Market-orientation allows companies to be proactive instead of responsive and therefore guide innovation in the long-term (Narver et al., 2004; Slater & Narver, 1998). In Article 1, it is found that knowledge of such latent needs may be unavailable from the customers and users may have to be contacted instead in the context of B2B manufacturing industry. The study also contributes by explicitly linking latent needs and tacit knowledge to radical innovation. The findings also suggest that reliance on explicit knowledge may, in fact, even be harmful for radical innovation, since it may direct innovation activities towards short-term problems and innovations with modest novelty.

7.2 RQ2: How do the capabilities of acquisition, assimilation, transformation, and exploitation manifest themselves in substituting internal R&D with supplier innovations?

Article 2 describes a form of open innovation in which the external knowledge is not integrated, but instead is commercialized in collaboration with the technology supplier using joint business models. Since the partner company supplies the new technology, no extensive internal R&D is needed. This approach is interesting, as it challenges the common assumption found in the literature that high internal R&D investments (and resulting absorptive capacity) are a requirement for inbound open innovation (Bianchi et al., 2016; Cohen & Levinthal, 1990; Dahlander & Gann, 2010). Open innovation is widely understood as a strategy to complement internal R&D (Dahlander & Gann,

2010; Hung & Chou, 2013), where, in addition to companies' internal resources, they tap into external sources for knowledge, ideas, and capacity (West & Bogers, 2014). It is often implied that the company in question has the main responsibility for managing the collaborative innovation projects and, for doing so, a certain level of technological proficiency is necessary (Cohen & Levinthal, 1990). Previous studies have, however, ignored situations where the buying firm has low R&D intensity and therefore a limited capacity to learn from new technological insights and implement them in development projects (Dahlander & Gann, 2010). The implicit assumption is that inbound open innovation cannot take place in such contexts. The findings of Article 2 suggest that there are different forms of inbound open innovation which have varying requirements and outcomes — a point which is sometimes absent in the abstract portrayals of open innovation. Based on the findings, it can be argued that not all forms of open innovation necessitate heavy investments in the development of technological proficiency prior to the partnership — even in the case of radical innovation projects. The kinds of arrangements described in the article are made attractive for the suppliers by giving them access to the focal company's capabilities that are needed to realize their incomplete business models (Dahan et al., 2010). However, such arrangements are not optimal when the aim is to engage in intensive learning (Sobrero & Roberts, 2001), since without internal R&D, the focal company's learning abilities are limited.

Regarding the search for new partners and promising technologies, which is identified as a key open innovation challenge (Badir & O'Connor, 2015; Enkel et al., 2009; Laursen & Salter, 2006), the findings of Article 2 suggest that to identify and evaluate potential companies with innovative technologies, they may conduct research activities, including internal pre-studies, collaborative research projects, gathering information via request for information procedures, and ordering sample products for testing. These examples emphasize that, for the purpose of partner identification and evaluation, research activities do not always need to be extensive. Small-scale investments may be sufficient for finding suitable partners in new technological areas. The study contributes to the open innovation literature by providing concrete examples of how different search strategies can be conducted in practice, thus addressing the question of how companies filter external knowledge (West & Bogers, 2014). In Article 2, innovation processes are launched by finding supplier companies which have already resolved relevant technological problems. The suppliers' technological capabilities are then combined with the focal company's internal marketing and sales capabilities to introduce new products that are delivered under a joint business model. Such an approach provides attractive opportunities for radical innovation, since companies may launch new products without major investments in technological development, which may allow them to benefit from advances in unfamiliar technology areas. Since the technologies are not developed internally, radical innovation is no longer managed only by the R&D and technology functions. Instead, other functions, such as purchasing, may have significant responsibilities. This may help reduce the increased inter-organizational complexity that is brought by the

increased number of external relationships (Kim & Wilemon, 2003). This finding is in line with a wider trend, where open innovation becomes a cross-functional effort between R&D and other organizational units (Brattström & Richtnér, 2014; Koufteros et al., 2005; Luzzini et al., 2015; Melander & Lakemond, 2015; Schiele, 2010).

Looking at the projects from the absorptive capacity perspective reveals that the substitution of internal R&D with supplier innovations sets new requirements to acquisition, transformation, and exploitation, which all emphasise the role of supplier management capabilities in the open innovation process. The findings suggest that while the assimilation capability does not strongly manifest itself in this context, the other three capabilities associated with the theory are still relevant. It is proposed that certain supplier management capabilities (cf. Foerstl et al., 2010; Reuter et al., 2010) are important for successfully carrying out open innovation projects with suppliers as they facilitate the acquisition, transformation, and exploitation of the suppliers' innovative technologies. The acquisition phase requires supply market intelligence that provides deep insights to suppliers' technologies and R&D resources. Furthermore, the transformation phase relies on buyer-supplier negotiations that are very demanding, involving complexities on agreeing on the business model, exclusivity, and risk and reward sharing. The contracts required for transformation were found to be complicated and strategically important for both parties, which stresses the need for negotiating and contracting capabilities. Finally, supplier relationship management and collaboration capabilities are proposed to promote the exploitation phase in the low R&D context. These findings contribute to the discussion on inbound open innovation and absorptive capacity as they suggest that in the absence of internal R&D companies may be able to build the ability to exploit external sources of innovation by developing proficiency in supplier management (Ateş et al., 2017). Low R&D intensity companies have been suggested to have a great need for external inputs to innovation but a low ability to benefit from it (Barge-Gil, 2010; Kim et al., 2016) and the findings increase understanding on how to increase this ability when the inputs are provided by suppliers. As open innovation activities diffuse beyond the high-tech industries it is valuable to identify processes which do not rely on high R&D investments (Chesbrough & Crowther, 2006; Spithoven et al., 2011).

7.3 RQ3: How do social integration mechanisms influence the absorption of radical ideas from unusual sources?

While it is often convenient for managers to search for new partners that are relatively similar to their own company or to work with their established partners (Birkinshaw et al., 2007), the extant literature strongly suggests that companies should reach out to unusual partners if they wish to promote radical innovation (Day & Schoemaker, 2004; O'Connor & McDermott, 2004; Phillips et al., 2006). It is also reported that there are often significant tendencies for organizations to reject ideas when they are not familiar with the idea source

(Antons & Piller, 2015; Cohen & Levinthal, 1990; de Araújo Burcharth et al., 2014; Katz & Allen, 1982). Unusual idea source may increase the perceived technological and market uncertainties associated with ideas as companies may be poorly equipped to evaluate their potential (Chiaroni et al., 2010). Combined with the radicalness of the ideas, the uncertainty levels may become particularly high (Chesbrough, 2006) and the managerial challenges converge on a question of how to reduce them to manageable levels.

Article 3 looks at how social integration mechanisms influence the performance of absorptive capacity capabilities and contributes to the understanding of the challenges companies may face when integrating radical ideas from unusual sources and the mechanisms that may help them in doing so. Each of the absorptive capacity capabilities (acquisition, assimilation, transformation, and exploitation) was found to be associated with a specific challenge: (1) connecting inventors with the R&D unit, (2) finding resources and motivation to investigate the idea and reduce uncertainty, (3) challenging perceptions of the company's goals and capabilities, and (4) leveraging organization-wide support and competences to introduce highly novel products. The origins of these challenges can be traced to the unusual idea source and idea radicality.

In usual situations where the ideas come from within the R&D unit or from familiar partners, the R&D unit benefits from socialisation mechanisms related to shared language, background, education, values, and norms. Unusual inventors, however, cannot benefit from these mechanisms and hence are initially less trusted and understood which generates a barrier to the adoption of their ideas. Another source of uncertainty is the radicalness of the idea as certain socialisation (shared values and norms) and systems (formalisation) mechanisms were found poorly suitable for addressing them. Radical ideas often challenge companies' existing capabilities and knowledge bases (Todorova & Durisin, 2007) and their potential and risks are difficult to evaluate in their early stages (Leifer et al., 2000). Hence, their absorption may require organizational culture and formal systems, such as decision-making criteria, which are tolerant of uncertainty and occasional failure

The combination of radicalness and unusual idea sources may therefore make organizations poorly able to utilise two types of social integration mechanisms – socialisation and systems mechanisms – which have been identified to benefit absorptive capacity and innovation in previous studies (Jansen et al., 2005; Lewin et al., 2010; Todorova & Durisin, 2007). The findings illustrate how these mechanisms may generate a tendency to reject innovative ideas from outsiders (Katz & Allen, 1982; Laursen & Salter, 2006). Under conditions of high uncertainty, idea absorption seems to rely mostly on coordination mechanisms.

In Article 3, it is proposed that, when there are major differences in the backgrounds and characteristics of new partners, it may be difficult to put the ideas that are received from them in use. This is because managers may be used to considering some characteristics, such as a proficiency in using certain technical language and a particular educational degree, as signs of expertise, and not all potential partners have these characteristics. Differences between

unusual external partners and managers in the focal company may thus become barriers to understanding each other and result in suspicions over whether ideas received from the other party are as feasible and noteworthy as proposed. Based on earlier research, it is known that similarities in partner companies' organizational structures, compensation policies, dominant logics, and knowledge bases affect how well external knowledge may be assimilated and exploited (Lane & Lubatkin, 1998). Article 3 extends these findings by identifying such a situation where the partner is an individual inventor and explaining it by underlying socialization mechanisms that facilitate communication and knowledge exchange (Jansen et al., 2005; Lewin et al., 2010; Todorova & Durisin, 2007).

Article 3 also reports how highly motivated individuals may overcome organizational barriers to radical innovation. Such individuals have been discussed in the literature under the concept of innovation champions (Chakrabarti, 1974; Day, 1994; Ettlie et al., 1984). They are found to be able to promote radical innovation projects despite resistance from the rest of the organization. The results suggest that innovation champions may operate in secret without an official approval, hence confirming earlier findings on the benefits of such secretly organized "bootlegging" activities for innovation (Augsdörfer, 2005; Criscuolo et al., 2013) in the context of radical innovation. The findings suggest that mechanisms which increase interactions and network formation within the organization, such as cross-functional interfaces and open-door policies, may promote the emergence of innovation champions by connecting inventors with those who have the power to make things happen. The study also supports the notion that there may be different types of innovation champions (Gemünden et al., 2007). Some may act as boundary-spanners, convincing decision-makers at different parts of the organization, while some may take a more direct role in using their position to allocate resources for the project. According to the study, radical innovations may not only "tend to" emerge bottom-up from individuals to the organization-level (Reid & de Brentani, 2004) – in some situations that may be the only option.

Radical innovation is often suggested to benefit from separate organizational units where uncertain ideas and projects which would be rejected from the mainstream organization can be incubated (Hill & Rothaermel, 2003; Leifer et al., 2001; O'Connor & Ayers, 2005; O'Connor & DeMartino, 2006; Rice et al., 2002). Some authors have proposed similar arrangements for open innovation (Bianchi et al., 2016; Chiaroni et al., 2010; Kirschbaum, 2005). Separate units may benefit inbound open innovation by bringing together the organization's dispersed know-how on open innovation and coordinating the internal collaboration between critical functions (Bianchi et al., 2016). Based on these thoughts, it can be argued that when a company wishes to increase its receptiveness to radical ideas from external sources, it may benefit from an independent organizational unit. Such a unit would potentially be able to reduce technological and market uncertainties arising from both radicalness and the external source and incubate them until they may be integrated in the mainstream organization.

7.4 RQ4: How may managers motivate individuals towards radical innovation work?

The majority of research on radical innovation focuses on company-level issues, such as organizational structures (Leifer et al., 2001; O'Connor & DeMartino, 2006) or innovation processes (Lynn et al., 1996; Veryzer, 1998). Recently there have been calls for research which addresses radical innovation development at the micro-level, i.e. individuals and teams (Alexander & van Knippenberg, 2014; Holahan et al., 2014; Kelley et al., 2011). In particular, the lack of individual motivation has been identified as a key barrier to the successful development of radical innovations (Alexander & van Knippenberg, 2014; O'Connor & McDermott, 2004). Article 4 takes a step in increasing understanding on how to overcome this barrier by investigating how managers may influence the motivation of individual developers towards radical innovation tasks.

In Article 4, a multi-level model is proposed and tested that draws from goal-setting theory, social cognitive theory, and radical innovation literature. The model proposes that there are multiple factors which influence the initial level of individual motivation for radical innovation development and moderate its effect on success in radical innovation development tasks. These factors are related to goal assignment and organizational support and they can be found at the individual, project team, and organization level, which indicates a high complexity in managing motivational issues. By investigating these factors at multiple levels the study extends previous research which has focused on single levels of analysis, such as individuals (Kelley et al., 2011) and teams (Alexander & van Knippenberg, 2014).

Goal assignment has been previously identified as an area where the majority of companies have room for improvement (Barczak et al., 2009). The study provides three distinct insights on goal assignment considering its effect on individual motivation. First, managers should identify strategic arenas (Cooper & Edgett, 2010), that is broadly defined domains which determine what kind of radical ideas are sought for. Second, they should acknowledge that radical innovation goals may conflict with incremental improvement goals which are often dominant in incumbent companies (Andriopoulos & Lewis, 2009). Employees should be provided with methods to prioritize between different goals. Third, radical innovation development tasks are often highly demanding and special attention should be paid to evaluating the skills of individual employees and matching them with suitable tasks.

Considering organizational support, the study finds that how certain managerial and organizational factors, such as high bureaucracy, and rewarding may influence individual motivation towards radical innovation tasks. Motivational issues are typically discussed in the context of organizational culture (Martins & Terblanche, 2003; Stringer, 2000). Article 4, however, shows that organizational structures and processes may as well have motivational effects. By linking these factors to concrete managerial actions that are in use in the studied companies, links can be established between such managerial methods and individual motivation. As an example, the benefits of iterative innovation process models are widely reported in the literature (Lynn

et al., 1996; McGrath, 2001). They are argued to work on the basis that they are able to reduce high technological and market uncertainties (Veryzer, 1998). Article 4 proposes an additional working mechanism, according to which iterations provide experiences of success that are typically rare in long and challenging radical innovation projects. Such experiences may increase the developers' beliefs in their own capabilities, which increases motivation and may manifest itself in improved work performance. Similarly, arrangements that provide radical innovation teams with independent status, for example in separate organizational units (Leifer et al., 2001), were found to increase motivation by reducing goal conflicts and improving resource allocation. The extant literature has addressed the benefits of such organizational units for radical innovation, but explicit links to motivation have been missing. By proposing such mechanisms, the study elaborates on the interdependencies between elements of the radical innovation capability at different levels (individual, team, organization) as well as between different management categories (processes, culture, organizational structures). The findings support the idea that the capability to develop radical innovations is a highly systemic one and that it consists of multiple interrelated elements which interact with each other (O'Connor, 2008).

7.5 Typology of managerial positions for promoting radical innovation with open innovation

Based on the extant literature, we can conclude that adopting open innovation practices can advance the development of radical innovations by giving access to a variety of resources and capabilities (Geffen & Rothenberg, 2000; Kelley et al., 2013; Kim et al., 2015), which can reduce uncertainties related to technologies and markets (Kennedy et al., 2016). However, at the same time, additional difficulties emerge related to the use of open innovation practices (Chiaroni et al., 2010; Hu et al., 2015). Companies may have difficulties in locating and processing relevant external knowledge, finding ways to trust and work with new partners, reducing negative attitudes towards radical innovation development tasks and the use of external knowledge, and managing innovation collaboration in situations, which require finding shared interests and operating models with external partners. Reportedly, there is variety in how companies are able to manage openness (Chatterji & Fabrizio, 2014; Gassmann et al., 2010) and radicalness (Sorescu et al., 2003) and facing these challenges simultaneously is likely to be demanding. Failing to manage this setting of particularly high uncertainty may lead to detrimental outcomes (Cheng & Shiu, 2015; Menguc et al., 2014; Ritala & Sainio, 2014).

Next, a typology of ways through which open innovation may promote radical innovation is presented (Figure 7). The typology draws from both the empirical studies presented in this dissertation and extant theory. Available positions within the typology are determined by two axes. First, whether a company adopts a reactive or proactive approach, that is, whether it actively seeks out opportunities for radical innovation from external sources or is more passive

and responsive to suggestions by others. Second, if the locus of innovation is within the company (internal) or outside it (external) (Gassmann & Enkel, 2004). The locus of innovation refers to who has the main responsibility and contributes the most towards the innovation. The axes should be thought of as continuous instead of discrete, as companies may combine both proactive and reactive approaches and there is a range of open innovation forms where the responsibilities and contributions of the external partners vary between mostly internal and mostly external (Geum et al., 2013; Koufteros et al., 2007; Petersen et al., 2005).

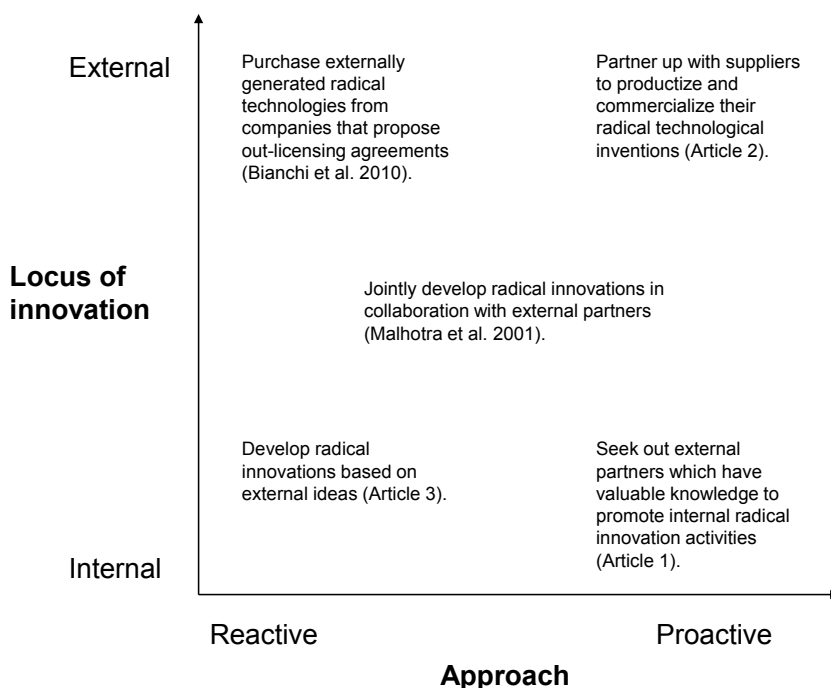


Figure 7. Examples of managerial positions for using open innovation to promote radical innovation.

The *proactive* approach can be considered to be more demanding than the reactive approach as effort is needed for searching for new radical innovation opportunities and selecting the best partners (Article 1; Article 2; Birkinshaw et al., 2007; Laursen & Salter, 2006). In contrast, the reactive approach does not require such systematic methods as it relies on ad hoc decision-making when a new opportunity emerges (Article 3; Winter, 2003). The downside of the reactive approach is that the proposed ideas and technologies may be perceived uncertain, as there may be no systematically maintained understanding of the “search and selection space” which would help to make sense of them (Article 3; Bessant et al. 2014). The reactive approach is likely to be effective in situations where the company has high attractiveness in terms of brand and reputation, production process capability, and innovation capability (Tanskanen & Aminoff, 2015), therefore increasing the potential partners’ expectations of the

outcomes of collaboration (Makkonen et al., 2016) making them more willing to share their ideas and innovations (Lichtenthaler, 2005; Spaeth et al., 2010; Wagner & Bode, 2014).

Turning now to the other axis. When the *locus of innovation* is found at the focal company, the demand for internal R&D capabilities and absorptive capacity are proposed to be high since the external knowledge must be fully internalized before it may be exploited (Article 3; Cohen & Levinthal, 1990; Zahra & George, 2002; Todorova & Durisin, 2007). In contrast, if the external partner is responsible for most of the development, capabilities for relationship management and negotiation are emphasized over internal R&D (Article 2). Moreover, to be considered a potential partner, the focal company needs to have some complementary assets that will attract the attention of the technology developers (Bianchi et al., 2010) and enable the combination of the assets into new innovations (Dyer & Singh, 1998). In addition to these options, a middle position may be described. It has been suggested that the development processes require the most effort when the development responsibilities between the company and its external partners are shared close to equally (Koufteros et al., 2007), reflecting an intermediate form between the extremes of strongly internal or external loci. This position is characterized by joint problem solving activities, which require intensive interactions and knowledge exchange (Dingler & Enkel, 2016; Kühne et al., 2013; Lakemond et al., 2016; Malhotra et al., 2001; Wagner & Hoegl, 2006).

Below, five positions depicted by the proposed typology are described:

- In the *reactive-internal* position, companies are receptive to external suggestions and conduct most of the development activities internally. To benefit from external inputs, they need to have appropriate channels via which they may be contacted (Ahmed, 1998) and mechanisms which reduce uncertainty related to the received knowledge and promote its integration (Article 3; Jansen et al., 2005).
- The *proactive-internal* approach describes a position where external knowledge and capabilities are actively sought out to promote internal innovation activities. While the external inputs may be used to reduce uncertainties related to internal radical innovation projects, effort is needed to conduct search activities and integrate the external knowledge (Article 1).
- An example of a *reactive-external* position would be a situation where technology developers use outbound open innovation methods to commercialize their radically novel technologies and contact the focal company to bring ideas to market faster than they could by themselves (Enkel et al., 2009) or to penetrate new markets (Bianchi et al., 2010).
- In the *proactive-external* position, companies are interested in relatively mature technologies that they can leverage to introduce radical innovations with low internal R&D effort. The lack of need for internal R&D reduces technological uncertainty, but collaboration is highly demanding since the outcomes are dependent on the company's ability to align its interests with the technology supplier and agree on contractual issues (Article 2).
- Finally, the *joint development* position covers much of the space between the four corners. It may be initiated by the focal company or the external partner and therefore be proactive or reactive.

Furthermore, the locus of innovation is in joint innovation activities and hence both parties have similar amount of responsibilities (or the other party has a slightly bigger role).

The typology introduced above has some implications for the debate on open innovation's benefits for radical innovation. First, it reveals that it is important not only to decide with whom to collaborate but also in which way because the chosen arrangements influence how they should be managed. As an example, high absorptive capacity may be needed when the locus of innovation is near the focal company (Cohen & Levinthal, 1990), whereas frequent communication may be necessary for joint development efforts (Malhotra et al., 2001). In the case of external locus of innovation, where the relationship aims for efficient commercialization instead of mutual learning (Bianchi et al., 2010), aligning the interests of the partners and agreeing on contracts is important (Article 2). Making this distinction between the various loci of innovation may be valuable, as the extant literature has been noted to be ambiguous in whether radical innovation benefits arise from the creation of new technologies or commercializing existing technologies into new products (Laursen, 2012).

Second, the findings suggest that companies may gain access to external knowledge via two distinct mechanisms: they may engage in an active search for new opportunities (Laursen, 2012; Zang et al., 2014) or invest in increasing their attractiveness to raise the number of received collaboration proposals (Tanskanen & Aminoff, 2015; Wagner & Bode, 2014). Of these, the former approach comes closer to the idea of developing a dynamic capability, defined as the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments, whereas the latter resembles ad hoc problem solving (Teece et al., 1997; Winter, 2003). The proactive approach may have the benefit of being more systematic and effective (Zollo & Winter, 2002), but building and maintaining the required capabilities is likely to require significant investments (Winter, 2003).

Third, based on the typology, it can be argued that it may not be useful to explain radical innovation outcomes with general-level constructs such as "openness" or "open innovation", since there are many distinct ways that companies may approach external relationships and the contents of the external inputs may vary from early-stage idea to mature technologies. The findings of this dissertation therefore support the view by West & Bogers (2014), according to which researchers need to be very clear in what they mean by innovation and open innovation in their studies.

7.6 Practical implications

The ultimate purpose of this dissertation is to help people solve practical problems in their work and other contexts. The potential impacts may be reached in two ways. First, the impacts may be indirect, where the findings become a part of the wider knowledge base of innovation and its management, which is investigated and applied by managers, consultants, policy makers, academics, and others seeking to understanding how to solve the challenges that

they face. In addition, more direct effects may be reached by presenting the main practical implications here, in the following paragraphs.

The findings push managers to examine what kind of uncertainties can be found in their operating environment and address them. They need to predict potential challenges and make sure their organizations are capable of resolving them. Significant changes in, for example, technological and market uncertainties, may mean that the management methods are not just less optimal, but may in fact become major barriers to innovation.

Regarding external linkages, the findings suggest that one size does not fit all, meaning that deciding on how to collaborate and with whom requires careful consideration. Whether the search is for mature technologies, fresh ideas, data, or experiential knowledge, makes a difference in where to look and what is needed from the organization. Thought should be given to matching the partners and methods to innovation goals, which may be anything from modest improvements to existing products and services to radical breakthroughs. Open innovation should hence not be thought as a simple technique or methodology but rather a more general idea of making use of the opportunities from collaboration. The findings from Article 1 imply that managers should wary of oversimplified models of, e.g. market orientation or customer focus, and critically evaluate their applicability to their industry. The relevant stakeholders and the knowledge that they possess may vary based on the industry context, and identifying the most relevant becomes is a key task for innovation managers. In particular, the findings propose that in the B2B industries a clear distinction should be made between users and customers and that their inputs to companies' innovation processes should be evaluated separately.

Companies may vary in how they use open innovation to promote radical innovation. Some may strongly rely on their internal capabilities which they complement with the knowledge and abilities of external partners. In other cases, the partners may have most of the development responsibilities, which lowers the requirements for internal innovation efforts. The findings from Article 2 indicate that if a company lacks expertise on those technologies that their external partners have developed, the partners cannot be treated merely as knowledge sources. Instead, highly collaborative approach to turning the technologies into new products and services is needed, and significant effort must be put into managing the relationships, aligning the partners' interests, and finding operating models that are beneficial for both the focal company and the external partner.

Most managers are well aware that sometimes organizations may face difficulties in integrating external ideas and innovations. What can be learned from Article 3 is that when the ideas are radical and they originate from new sources, managers should expect that these difficulties are intensified. They will, at the same time, face organizational rigidities that arise both from the novelty of the ideas and of their origins. In these kind of situations, it is expected that the ideas will not survive for long if they are left on their own. To ensure that such ideas are thoroughly investigated, managers can incubate them, for example in a specific organizational unit, before integrating them into the

regular innovation process in order to decrease some of the uncertainties associated with them. If they are left to compete with other ideas, which might be more incremental or generated within the R&D unit, in the very beginning, they are likely to be rejected as too risky.

It is also evident that — especially under challenging circumstances such as in the case of radical innovation projects — ignoring the human element in innovation is not an option. Innovations always trace back to the actions of individuals and ensuring their motivation and well-being should be included in the managers' agenda. A key target should be to make sure that the whole organization sees the value in developing new innovations and is willing to help when needed. Article 4 reveals that motivation is not just a matter of leadership or culture. Instead, many different types of managerial choices, from deciding on organizational structures to establishing new product development process models, may influence the developers' motivation. It is known that when developing radical innovations, it is crucial that the developers are able to maintain their motivation. The implication of this dissertation is that motivational considerations should be included in all decisions which may have direct or indirect effects on the development of radical innovations. Articles 1–3 suggest that developing radical innovations in an open environment may necessitate changes in processes, capabilities, and organizational structures. In making such changes, it is particularly important to address motivational issues, since their benefits may remain low if the individual-level innovation drivers are missing.

The typology presented in Figure 7 may be helpful for managers who wish to navigate the open environment for providing a boost to their radical innovation performance. Based on their existing strengths and other strategic priorities, companies may approach open innovation in diverse ways. Companies with high internal R&D may wish to leverage related competences and conduct most of the development tasks internally, whereas those who do not have existing expertise in-house may benefit from exploring arrangements where main technology development contributions come from external partners. Furthermore, open innovation may be initiated by establishing communication channels for others to propose collaboration or proactively seek new opportunities. More reactive approaches may work for prestigious companies who are considered attractive partners by many, whereas others may need to invest in active search for suitable candidates. By analysing their strengths and weaknesses, managers may determine which forms of open innovation would be the most suitable for reaching their innovation goals and develop new capabilities accordingly.

7.7 Limitations and recommendations for further research

All research entails limitations that arise from the chosen scope, methods, and theory that should be addressed. The identified limitations can also be used to identify avenues for further research.

One evident limitation which affects the transferability of the findings to other contexts is the type of companies studied. Research on innovation management often focuses on incumbent companies, that is, large corporations with an established market position. This is because such companies typically have the resources to implement systematic innovation management methods (Damanpour & Aravind, 2012; Rohrbeck et al., 2009), which gives researchers the opportunity to examine how different managerial systems work. Also this dissertation investigates incumbent companies. Radical innovation and open innovation are, however, relevant issues also for small and medium-sized enterprises (Salavou & Lioukas, 2003; van de Vrande et al., 2009), but the managerial challenges and optimal strategies may vary with company size. The issue of how relevant the findings from incumbent companies are to smaller companies would benefit from further research. Also, the connections between radical innovation literature and related literatures which address similar issues in new companies (e.g., entrepreneurship) could be strengthened.

Article 4 investigates the topic of individual motivation in radical innovation development but focuses on the internal matters of the organizations and does not address motivational issues in situations where radical innovation is promoted by the means of open innovation. Motivational issues have been acknowledged also in the open innovation literature (de Araújo Burcharth et al., 2014) and Article 3 suggests that a lack of motivation to develop radical ideas from external sources may be a major barrier to realizing their benefits. Therefore, future studies of context where radical innovation is promoted by open innovation would be valuable as they could provide new insights on how to support employee motivation.

Considering external linkages, this dissertation focuses mainly on dyadic relationships between the focal company and a single external actor. Innovation often occurs within wider intra-organizational settings such as triads, chains, networks, and ecosystems. These settings may bring about additional challenges that should be acknowledged. If the number of actors increases the management of external collaboration is likely to become more complex and challenging (Cassiman & Valentini, 2016; Elmquist et al., 2009). Therefore, it becomes of interest how companies can orchestrate networks of many companies or participate in wider ecosystems to introduce radical innovations.

The methodologies of the empirical studies are subject to further limitations. The studies do not aim to make statistical generalizations about larger populations. Instead, their purpose is to provide new theoretical insights into the phenomena of radical innovation management. The findings are proposed to be potentially transferable to empirical contexts of high uncertainty, other than the ones perented in this dissertation, more specifically to those where radical innovation is promoted by open innovation, and effort has been put into describing the empirical contexts of the studies in detail. Limits of the domains to which the insights could be transferred can, however, not be defined precisely. Nevertheless, it is likely that the results from, for example, Article 1, which addresses the B2B manufacturing industry and Article 3, which addresses

the steel industry, cannot be straightforwardly applied to significantly different industries.

In this dissertation, radical innovations are defined as products, services, or processes which encompass novel technologies or require new market structures, and which have the potential to create paradigm shifts at the world, market, or industry level. This definition includes high-novelty innovations of different types: competency-enhancing and competency-destroying innovations, innovations based on breakthrough technologies that are targeted at existing markets and innovations that have moderate technological novelty that are targeted at new markets, and different combinations of these. It has been argued that all these have sufficient similarities for it to make sense to discuss them as a distinct group of innovation (O'Connor, 2008), and that barriers to radical innovation are determined more by the characteristics of firms, markets, and innovation process phases than the type of radicalness (Sandberg & Aarikka-Stenroos, 2014). Nevertheless, such a broad definition of radical innovation sets limits to the transferability of the findings as different innovation types within the umbrella of radical innovation have their special characteristics and demands (Markides, 2006).

Similarly, this dissertation draws strongly from the views of uncertainty in radical innovation by O'Connor and Rice (2013a) who distinguish several different types of uncertainty and help concretize the abstract construct. The majority of the literature on radical innovation and open innovation, however, discusses uncertainty without clear definitions or references to what kind of uncertainty and complexity they actually refer to. It should hence be noted that the discussion in general is not very well grounded in clear definitions. Aiming for conceptual clarity is important because as it may enable managers to describe their innovation challenges more precisely. Furthermore, more conceptual clarity would help in understanding how to respond to these challenges. Currently, the context of high uncertainty is often described in rather general terms, and there is evident value in putting effort in identifying the precise sources of uncertainty.

8. Conclusions

Innovation is becoming increasingly important for all kinds of companies, being critical for their competitiveness and growth. Often the improvement of existing products and services is not enough to ensure competitive advantage in the long term. In such cases, learning how to develop radical innovations is highly valuable. Radical innovations are, however, associated with high levels of uncertainty, which makes their development challenging. Companies may be proficient in developing incremental innovations while performing poorly in developing radical innovations. Previous research has investigated how certain processes, organizational structures, culture, and external linkages may promote radical innovation. However, the ability to develop radical innovations is difficult to achieve and more understanding is needed on the challenges associated with radical innovation and methods to overcome them.

With an emphasis on the open aspects of innovation, this dissertation has increased understanding on the problem of how companies may develop radical innovations by investigating four specific issues: 1) interactions with customers and users, 2) substituting internal R&D with suppliers' radical technologies, 3) integrating radical ideas from unusual sources, and 4) the management of developers' individual motivation.

Regarding the interactions with customers and users, it is found that these two stakeholder groups may differ in what kind of knowledge they are able to provide, and therefore they may have distinct effects on radical innovation and their involvement may require different managerial practices. In the B2B manufacturing industries undergoing digitization, customers may be unable to provide guidance for radical innovation and companies may instead benefit from interacting with users for this purpose.

The findings on the substitution of internal R&D with suppliers' radical technologies indicate that high investments in internal R&D are not necessary for engaging in open innovation projects with suppliers, but that these kinds of projects require supplier management capabilities for establishing and managing successful collaboration between the parties.

On the third issue, the findings suggest that when companies aim to integrate radical ideas outside their usual idea sources, mechanisms which are normally responsible for turning ideas into new products may not be available due to high uncertainties, and managers should promote the use of coordination

mechanisms that facilitate knowledge exchange across disciplinary and hierarchical borders.

Finally, the findings related to the fourth issue indicate that individual motivation towards radical innovation development may be influenced by goal assignment and organizational support at individual, team, and organization level, and that many elements of a company's innovation management system may have – sometimes unexpected – effects on individual motivation. The findings indicate that in making organizational and managerial changes, such as those suggested by the other studies in this dissertation, their motivational effects should be carefully considered.

Altogether, the findings of this dissertation suggest that the difficulties associated with development of radical innovations cannot be overcome by focusing on a single managerial category, such as processes, organizational structures, culture, or external linkages. These categories are interlinked and the benefits from one of them may not be realized if the others do not support radical innovation sufficiently. The empirical studies in this dissertation illustrate several such connections between different managerial categories. Opening up to stakeholders such customers, users, suppliers, and entrepreneurs needs to be matched with processes, structures, and culture which support the search, integration, and use of external inputs and the management of collaborative relationships. To advance radical innovation with external knowledge, ideas, and technologies, there needs to be processes to identify and use them, structures which allow their combination with the company's existing knowledge base, and culture which does not shun collaboration with external partners and working under high uncertainty. Furthermore, in Article 4 it is found that motivation, which is most often discussed as an outcome of organizational culture, is closely affected also by what kind of formal innovation processes the developers must follow and what kind of organizational structures there are in place. Therefore, to address the issue of a lack of motivation, it is not sufficient to focus on culture and leadership. Instead, the entire management system should be analysed from the point of view of motivation.

Many organizations have identified the need for more radical innovations but struggle in reaching this aim. Adopting open innovation methods has been shown to be helpful but openness carries with it additional managerial challenges. For those companies, which have traditionally focused on incremental and closed innovation, the extension to radical and open innovation may be remarkably challenging. This dissertation has hopefully been able to shine some light on this endeavour.

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